AIR POLLUTION AND INCIDENCE OF MORBID CONDITIONS IN BANGALORE CITY

PROJECT REPORT

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BANGALORE-560 012

OCTOBER 1990

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AIR POLLUTION AND INCIDENCE OF MORBID CONDITIONS IN BANGALORE CITY

COMMUNITY HEALTH CELL

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FOREWORD

Modern urban living has brought in the wake of its many technological conveniences the threat of environmental hazards. These hazards are partly due to concentration of industries in cities and partly due to technology needed to support large masses of people in their rather confined areas. Land, water and air are all, to a more or less degree polluted in the urban areas.

Factories, automobiles and domestic fuel burning contribute to the pollution of air. The polluted air affects the health of people adversely. It is this aspect that is the target of this study.

The project was taken up at the instance of Prof A K N Reddy of the Management Studies department and funded by the Karnataka State Council for Science and Technology vide their letter N0.6.8.13/APBC/2260 dated 26th November 1987. Initially the project was of two years duration but change in the original research design, made during data collection, resulted in extension both of duration and expenses which were approved generously by the KSCST Vide their letter No. 6.3.08/MAP/1752 dated 6th October 1989.

The project was proposed with the objectives of studying air pollution and general morbidity of the population of Bangalore and of relating them. The task in the project was more involved

and complicated than was foreseen at the time of proposal. It opened virtually a Pandora's box and unfolded the appreciation that much larger studies than we intended, were needed to meet the objectives, that we had chewed more than we could digest and that, at best, this study could only be explorative.

However, many interseting aspects of pollution and morbidity have emerged from the research attempt apart from a very good understanding of the air quality in Bangalore. Two of them are the concept of cumulative pollution and the transition of morbidity states. More than these the study has given an invaluable experience and groundwork for further useful and comprehensive studies by the department.

Dr.H.P.Ramachandra Rao, the author of the report and Fellow in the project, has shown a lot of perseverance and has put in considerable hardwork both in the field studies and at the computer keyboard, in order to bring to completion the project and its report.

It was a memorable experience for us to have co-ordinated the project as convenors and to have interacted administratively with both KSCST and Dr.Rao.

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INTRODUCTION

CHAPTER 1
INTRODUCTION

1.1 GENERAL CONDITIONS OF AIR QUALITY IN BANGALORE CITY

Bangalore metropolis is one of the fastest growing cities in the Asian continent. It is the fifth largest city in India, but considering the rate of growth recorded in the recent past, it is observed that this city is perhaps the fastest growing one. According to a study conducted by Indian Space Research Organisation at Bangalore in 1985, the actual built up area of the city has increased from 178 to 265 square kilometers during the years 1980 to 1985. This study was based upon integrating topographic maps and satellite imagery. It indicates that expansion in land use for the purposes of residential, commercial and small industrial buildings has replaced the natural landscape such as parks, fresh water ponds, lakes and farming land mainly. As a result of this, there is considerable limit being imposed upon the availability of clean air necessary for healthy breathing of the human communities living in the vicinity.

The actual population growth in many parts of the city has attained almost an exponential pattern. The current population figure is around 50 lakhs and the projections for the future indicate that within the next decade there will be nearly 10 million people living in this city (Health of Metropolis, 1989). The major concern now is that the heart of the city (or its corporation limits which is confined to around 140 square kilometer area) is showing excessive population density. It varies between

20,000 and 1,20,000 persons per square kilometer in the 64 divisions, as estimated from the 1981 national census records. As the population density increases there is an increased demand for maintenance of sanitation and effective waste disposal in the city. Out of these, the aerial waste disposal triggered by domestic, commercial and industrial fuel consumption leaves behind enormous amounts of heat, smoke, aerosols and gaseous material into the surroundings almost uninterruptedly. The automotives used for transport purposes lack certain basic road infra-structure resulting in excessive congestion in the critical commercial regions of the city. There are at present more than 5 lakh vehicles cruising through the city road network. Nearly 70 percent of these vehicles are two wheelers used by the private owners and the rest are public transports such as autos, taxies, buses and goods vehicles. According to an estimate in 1987, most of the critical regions in the city exceeded the permissible standards of clean air, if not, are stated to be expected to exceed within the next couple of years if present trends of traffic congestion continued in the city (Ramachandra Rao,1987). These estimates are carried out for emissions such as Carbon monoxide, Oxides of Nitrogen and Hydro-carbons generated by automotive combustion of petroleum based fuels. (By mere number alone the city is ranked second highest in automobile traffic, whereas Delhi, the capital city of India is the foremost with nearly 15 lakh vehicles.)

Apart from the combustion of fuels, the biogenic material from the weeds such as parthenium and fungus growth

during and after the monsoon period inflict upon public health morbidity such as respiratory, circulatory and allied diseases. Considering the inadequacy of available open and lung spaces for better air quality maintenance and the phenomenal increase in pollution generating sources which are active in the city there is considerable scope for (investigating) assesing the environmental impact in particular.

In the past, not many attempts have been made to ascertain the association between air quality and health morbidity in the city. One of the reasons for this could be that in the past decades the city of Bangalore had the distinct reputation for its cleanliness and freshness because of gardens and parks. Often, it was cosidered as the safest place for disease sensitive and old people to settle down for the rest of their lives. The situation at present is definitely not so. From the sporadic health information that is available it is conceivable that the allergic and chronic cardio-pulmonary diseases are on the upsurge in Bangalore. Apart from the information generated in the ICMR (Indian Council of Medical Research) reports and the Department of Economics and Statistics, Government of Karnataka, there are only a few studies reported to address the problem of association between general health morbidity and ambient air quality in the city. A few studies on industrial workers such as printing press employees on lead poisoning (Prabhakaran and Hemantha Murthy, 1988), or on the symptoms of respiratory and cardiac illnesses among traffic police personnel on duty (Annual Report, Regional Occupational Health Center, 1988) illustrate the deteriorating

ambient air quality. Yet, health studies pertaining to general (human) community are wanting from the point of assessing the influence of the prevailing atmospheric conditions on public health in the city.

1.2 TYPES OF STUDIES NEEDED AND RELEVANCE IN BANGALORE

With the explosive growth pattern in population density and influx of energy intensive and pollution generating technologies, it can be stated that the ambient air quality in the city of Bangalore is worth exploring. Certain steps in diffusing this situation have been taken by the government agencies such as Department of Health, Office of the Commissioner of Transport and Karnataka State Pollution Control Board through certain specific guidelines put forward by Corporation bodies, Central Boards of Pollution Control and Prevention, and Department of Ecology and Environment. In this respect, general public awareness campaigns held by these agencies are claimed to be the first of their kind among Indian cities (personal communication with commissioner of Transport, Government of Karnataka, Sept 1989) and are quite beneficial.

Broad guidelines have been set up for abatement procedures by the 1981 "Air Act" (Prevention and Control of Pollution, Article 48A and 51A; 42nd Amendment) especially to contain the ambient air quality within certain permissible limits. But, these can become meaningfully effective if such measures are corroborated through health impact studies specifically evolved on scientific grounds and investigated on the basis of prevailing local conditions in human communities. This, however, calls for

long term studies of the types normally held after the historical pollution episodes in many modern cities of the world. In short, it can be mentioned that the investigations of the type of environmental epidemiology are needed which takes into account an exploratory evidence for association if any, between health morbidity and environmental agents causing poor air quality.

At present, there has been a widespread interest among researchers and environmentalists to check epidemiological information especially through mortality and morbidity records in most of the cities. Such studies have been taken up even without posing any specific questions (WHO Environmental Health Criteria 27, 1983). Further, associations, if any, between pollution episodes and epidemiological upsurges are treated for detailed investigations. The reason behind such a venture is that it is in fact, difficult to envisage a single most causal agent responsible for upsurge in mass mortality and morbidity among the general public. It is, however, important to notice that the information generated through such studies are hypotheticaly tested through future prospective epidemiological investigations and time series data. Some of these details are presented in the next chapter. Coming back to the likely environmental problems faced by the population of Bangalore city, it can be stated that there is wide scope for investigating the prevalent ambient air quality vis-a-vis general health morbidity.

The respiratory nutrient media of the general public, that is of present concern, can be said to be polluted from

various other considerations too. Like for example, the pollution damages to flora and fauna, corrosive actions on historical monuments and such other valuable property, effects on visibility and climate are those which are often refered to be associated with the problems of direct health damages in human communities. In fact, the present trends are in line with examining the human breathing media from an ecosystem's point, wholly because that the humans are basically a link in the complex chain of interacting organisms in a global environment. It is precisely because of such reasons the anti-pollution campaigns have gained momentum in modern day civilization. In these the concepts of pollution exposures are widely explored both from scientific and community hygiene points of view.

There are two types of exposures which are considered for indepth analysis and investigations in air pollution literature. They are acute and chronic exposures. These exposures are those investigated especially for pollutants like airborne particulate matter and Sulphur dioxide in many of the cities in the world. The acute exposures arise out of a burst of accumulation of these pollutants, either localised are widespread, in the ambient air during the occurance of episodes. The chronic exposures are termed mainly as research concepts and are assumed to be causing damages through some kind of combinatorial and cumulative effects on the human body.

At present, the preventive measures taken through prescribing permissible standards have a deep rooted rationale from the lessons learnt from investigations of the acute

exposures. There are several claims made even among the scientific communities that such acute episodes will be prevented from relapsing in future at least in the developed nations (Lipfert, 1985). Quite an amount of effort is therefore put in recent decades both at the national and international levels through various researches investigating the chronic exposures. Among the important results are the development of measurement techniques of personal exposures and the ventilation models which are breakthrough advances in the study of exposure estimation relationships.

In these models the personal exposures of individuals, in an urban atmosphere are accounted for by their movements through risk-prone areas in the city. The exposure content is derived as a dosage of toxic material which can be quantified on an individual basis, thereby arriving at specific conclusions as to the possible effects on human body. However, keeping the levels of pollutant concentrations in ambient air within the standards far below those that were noticed during acute episodes have become a normal procedure. It is certainly understandable that the situation is different in the developing countries of the world because of lack of infra-structural facilities to monitor and contain the pollution level within standards. Of course, there are global networks of monitoring stations which are actively organised by national and international agencies. Right now, national networks of pollution monitoring stations (National Environmental Engineering Research Institute, 1985) have been installed in India covering most of the major cities.

The routine monitoring done by industries and certain research organisations as well as governmental agencies such as the Karnataka State Pollution Control Board in Bangalore are also in line with the national interests and current trends of pollution awareness in many parts of the world. The pollutants normally monitored in these studies at several stations are airborne particulate matter and gases such as Oxides of Nitrogen and Sulphur. These are called the criteria pollutants investigated extensively in modern cities because of their widespread effects. They are known to enter the human body through the respiratory media and remain either toxic or quiscent. It is yet to be discovered as to what specific diseases that can arise because of their accumulation. The practice is to realise the effects only after the acute episodes because the health morbidity data from the past records are quite inadequate. So, the records indicating illnesses prevalent in cities are an invaluable tool in the hands of environmental epidemiologist to explore the situation appropriately and are worth generating year by year. Such information also helps in planning road networks, siting the industrial, residential and commercial concerns and various other activities in the interest of preserving the health and well being of urban communities.

1.3 RESEARCH EFFORTS ENVISAGED DURING THE PRESENT STUDY

In the present study, an attempt will be made to assess concurrently the air quality and the health morbidity. The scheme for working out a feasible research design is

undertaken after an initial exploratory study on available data with respect to ambient air quality monitoring and health morbidity. It is, however envisaged that a two stage research design is beneficial and feasible. The stages are, firstly a retrospective data analysis to ascertain the air quality in Bangalore and secondly, a prospective epidemiological survey.

In the first stage of investigations the pollutants monitored in the city on a regular basis are considered for analysis. Most importantly the literature pertaining to the criterion of selecting these pollutants for the present study are explained (Chapter 2 - Literature Back up). Based on the information a prospective epidemiological survey is conducted at two points in time separated by a period of one year. It is to be noted that the initial period of one year is taken, because the study is only an exploratory investigation. The change in health morbidity between the two points in one year are investigated further for examining for possible association with the ambient air quality during this period.

1.4 OBJECTIVES OF THE PRESENT STUDY

The prime objectives of the present study are limited by the availability of information regarding ambient air quality and health morbidity. It is to be appreciated that the scope of the present study is of an exploratory one. However long term studies are desirable in order to describe a meaningful relationship between the two.

The objectives are :

(i) to ascertain the retrospective ambient air quality with respect to spatial distribution and seasonality characteristics of important pollutants monitored through secondary data in Bangalore city,

(ii) to identify zones of high pollution risk population with respect to the ambient air quality prevailing in the region and select zones for study, and choose the population samples for a prospective epidemiological survey,

(iii) to estimate also the prospective and integrated exposure levels for the selected sample of subjects,

(iv) to investigate the extent of prevalence and incidence of health morbidity in sampled subjects in the selected zones, and finally

(v) to investigate possible associtions if any, between the pollution exposure and health morbidity among the selected general population in the city.

The overall structure of the present report purports at presenting the information generated in fulfilling the above mentioned objectives through specific investigations. In Chapter 2 is described the literature back up to assess the existing state of the art and comprehend the nature of work envisaged with reference to available information. In Chapter 3, the research

design and the methods adapted during the two stage investigations are described. Chapter 4 presents the analysis and results of the investigations where emphasis is laid on understanding the transition of diseases under the given environmental conditions and exposure to major pollutants in the city. Finally in Chapter 5, Summary analysis of the present investigations are made and the specific findings of the study are presented.

LITERATURE BACKUP

CHAPTER 2

LITERATURE BACKUP

2.1 INTRODUCTION

The literature on air pollution studies from all over the world is quite extensive and the same is dealt in the national and inter-national documents on air pollution impact in developed countries of the world. The World Health Organisation has been the main contributing agency in periodically up-dating such information for the benefit of mankind (WHO offset publications, Environmental and toxicological criteria documents and comprehensive review articles). The environmental criteria documents published by the Environmental Protection Agency (EPA) at United States of America is another source which provides invaluable information for the researchers, scientists, technologists, environmentalists, chemical engineers, city planners including statutory agencies and those wish to keep the ambient air clean in many developing nations.

It is not practicable and desirable to provide a complete review of all developments in the pollution aspects in a study like the present one. However, salient features pertaining to some specific pollutant types and their likely impact upon the human communities particularly with reference to health morbidity and mortality is certainly relevent in the present context.

As mentioned in chapter 1, the criteria of pollutants

studied depend upon the type of damages caused by them. Important among these are the historical episodes of acute exposures in human communities in various cities in the world. Because of the widespread damages like mass mortality and morbidity noticed during such episodes, the events have triggered further research into the areas of environmental toxicology, epidemiology, human ecology, bio-statistics and allied fields. As a result of this, it is possible to get considerable information on time series survival data of human communities from among the nations where episodes have occurred and deemed to occur in the future because of similar conditions being noticed through national and international networks of monitoring and surveillence. Secondly, the semi-controlled field experimental studies also provide much information on chronic exposures to pollutants in the ambient air. In fact, these three types of studies have become the basis for prescribing the permissible standards of air quality depending upon the priority given for local activity and economic criteria. It is likely that maintenance of such standards in any part of the globe will have a hidden risk element apart from several unknown factors yet to be explored.

In the present chapter, the pollutants generally noticed in the ambient air surrounding Bangalore only are considered and emphasis is laid on dealing with the information pertaining to their nature of impact on the general populations residing in the city. In this respect three important pollutants viz., airborne particulate matter, Oxides of Nitrogen and Sulphur are

dealt with in considerable detail by many agencies.

2.2 AIR QUALITY CRITERIA OF POLLUTANT TYPES PRESENT IN MODERN CITIES

Perhaps, even a layman senses the bad air entering his surroundings while he is commuting through the congested parts of a modern city. More appaling aspects of this are appreciated while observing the aesthetic components of a clear and transparently visible atmosphere being disturbed by smoke, dirt, smog, smell and noise due to busy vehicular traffic, plumes and flames of gases coming out of roof-top stacks from factories, odorous chemicals discharged into the atmosphere by manufacturing and processing units, or from the metropoliton incinerators and garbage cans etc. Yet, the harmful effects of bad air (pollutants) can not be better evaluated than by an analysis of the quality and quantity of air that is respired by humans to access in terms of the health damage that they can cause.

Normal air contains roughly 78 % of inert Nitrogen by volume, 21.7 % of Oxygen, 0.03 % Carbon dioxide and the rest are rare earth gases. The pollutants that are introduced into the air are of micro concentrations normally measured as parts per million or micro-grams per cubic meter of air, and often as parts per billion. Yet, they can be quite harmful to humans and other natural inhabitants because of their toxicity and allied chemical properties.

By definition air pollution means "the introduction by man, directly or indirectly, of substances or energy into the

environment resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems, and impair or interfere with amenities and other legitimate uses of the environment" (OECD Document on 'principles concerning transfrontier pollution', 1976).

Considering the context of the present study, it is worthwhile restricting the discussions to the pollutant types studied extensively in literature and their harmful effects on human health as experienced in an urban community. The other aspects as to the extent of the meaning of pollution as referred in the above stated definition can be separately treated in other contexts. Here "pollution caused by man is meant specifically to draw the attention of the reader to all those human activities such as personal, domestic, transport, commercial, industrial and other urban routines which add pollutants into the surroundings". It is in fact, the developmental activities of economic value or the rapid industrialization process introduced in a localised urban community which is responsible for the present day pollution impacts in cities.

It is the immediate ambient air quality governed by the specific location and the persons staying in the locality that determines the criterion of pollutants. Normally the human communities in the vicinity breathe through the ambient media resulting in exposures. The exposure responses can be varied in intensity and duration. Thus there are two types of exposures (acute and chronic) which determine the dose-response relationships. For example, the smoke density present in a highly

congested area results in deposition of carbonaceous material inside the respiratory tract and lungs causing respiratory tract infestations and constrictive or obstructive type of lung diseases.

Often certain pollutants like Carbon monoxide and Lead can pass through the respiratory barriers thereby entering the blood stream. The general pollutants of these types and the others as shown in table 2.1 are recognised to be the causes for increased cardio-respiratory diseases, allergic skin and subcutaneous disorders, lowering of the thresholds of immunity reactions in the infectious types of diseases, and carcinogenic impacts. Thus the major criterion of air quality maintenance in cities is considered as the health criterion of humans. There are several methods of investigation as described under environmental health criteria (Guidelines on studies in Environmental Epidemiology, WHO, 1983) and are used as the basis for establishing the cause and effect relationship. Generally, these investigations prescribe simultaneous methods of assessing the air quality and likely health effects in terms of morbidity and mortality indices.

Out of the many physical factors that vary the ambient air quality the diffusion gradients of pollutant concentrations influenced by wind flow and its direction, ambient temperature, humidity and other weather related factors (Fuchs, 1964) are important. The seasonal variations in air quality with reference to specific pollutant types have been shown to cause acute conditions as observed in many westren cities, like Los

Angeles, New York and London. The temperature differences at earth surface and in the ambient air which show marked differences during the winter months can give raise to inversions in air media. In these circumstances the acute concentrations of pollutants in the physiological breathing media have been shown to precipitate illnesses particularly affecting the aged, children, and sensitive persons. The pollutant types causing these phenomenal damages are,by and large, the smoke related particulate matter and Sulphur dioxide emitted by the combustion of fossil fuels like coke,coal and oil.

It is also important to note certain epidemiological features of environmental agents. In communities where the general health conditions are affected by such factors as heridity and ethnicity, infections and dietary origin they are further influenced by the bad air quality surrounding the regions. Often, many of the attempts to find cause and effect relationship between pollution and morbidity suffer from confounding factors as mentioned above. At the same time it is difficult to simulate under laboratory conditions the ambient air qualities as observed during epidemics and subject humans into experimental regimes. Perhaps the experimental animal studies show better results in this regard but, suffer from serious drawbacks because of diversity of responses between animals and human beings.

2.2.1 POLLUTION AND POLLUTANT TYPES OF URBAN ATMOSPHERES

There is no modern city that does not have pollution and diseases like Chronic Bronchitis are commonly attributed to the

Table 2.1 General pollutant types found in urban atmospheres

Type	Class of Compounds	Typical members	Important sources
AIRBORNE SUSPENDED MATTER	(a) Solid Particulate matter.	Dust, smoke, flyash, carbonaceous matter, trace metals Pb, Cd, Hg, etc.	Mines and quarries, pottery and ceramic factory stacks, power plants
	(b) Liquid droplets	Fumes, oil, tar, mists	Auto-exhaust, road building, organic industry
	(c) Derived products of photochemical reactions and particulates from reactions of gases	Photochemical smog, sulphate aerosols etc.	Sulphuric acid and fertilizer plants, General industrial particulate emission
INORGANIC	(a) Oxides of Sulphur	SO2, SO3, H2SO4	Power stations, sulphuric acid plants, oil refining, domestic use of coal
	(b) Oxides of Nitrogen	NO2, No, HNO3	Auto-exhaust, acid manufacture
	(c) Carbon compounds	CO, CO2	Auto-exhaust, blast furnaces
	(d) Oxidants	O3, PAN	Photochemical reactions in atmosphere
	(e) Others	NH3, H2S, HF, Cl2	Rayon plants, tanning industry, dye manufacture, aluminium industry
ORGANIC	(a) Hydrocarbons	C1-C5 group of compounds, benzene and derivatives	Oil refining, auto-exhaust
	(b) Aldehydes, ketones	Formaldehyde,	Organic industry
	(c) Other Organics	Bezo(a) pyrene, mercaptans, Chlorofluro-carbons, etc.	Coal gas plants, auto-exhausts, organic chemical industry, refrigeration

(Source: Misra and Sadasivan, 1980)

long periods of breathing polluted air by humans. One of the major concerns of recent origin is that the urban development is offset by the perpetual use of fuels that generate energy and pollutants in a centralised and confined area. It causes degradation of common resources such as air, water and land. However under acute conditions even the air pollutants can lead to disastrous health hazards. The common pollutants which are of such concern are shown in table 2.1. Often these pollutants are refered as "criteria pollutants" because of their harmful effects like mass mortality and morbidity as recorded during episodes in cities like New York, London, and Los Angeles (Logan, 1953; Schrenk, 1946; Firket, 1936). The most important point is the statistical association noticed between higher smoke density with Sulphur dioxide and excess death rates with illnesses among the general public during these events. There are three types of pollutants under the broad categories such as (i) airborne particulate matter, (ii) inorganic gases such as Oxides of Sulphur and Nitrogen, Carbonaceous gases, and (iii) carcinogenic organic substances like hydro-carbons, aldehydes and others normally present in industrial and urban localities.

NATURE AND IMPACT OF AIRBORNE PARTICULATE MATTER (SMOKE DENSITY) ON HUMAN HEALTH

There is considerable diversity in particulate type and concentrations in airborne suspended matter as can be seen from table 2.1. But, these types of pollutants are widely present as a result of both natural and artificial sources and activities. Listed in the above mentioned table are three types of particu-

late matter, and the first two (primary particulates) are not very reactive within the ambient media. But the third one (secondary particles) is highly reactive and has been shown to cause many ill effects on humans.

In broad terms the airborne particulate mass tends to cluster around two size groups, such as (i) coarse particles (larger than 2 to 3 micrometer in diameter) and (ii) fine particles (smaller than 2 to 3 micrometer in diameter). Among the fine particles, sulphates, carbonaceous material, ammonium and lead nitrate are commonly noticed and they often tend to cause serious 'smog' episodes (Mclear, 1973). Coarse particles consist of oxides of silicon, aluminium, calcium and iron, as well as calcium carbonate, sea salt and material such as fire particles, and vegetation related particles (e.g., pollen, spores).

The carbonaceous fine particles include elemental carbon (graphite and soot) and nonvolatile organic carbon (hydrocarbons emitted in combustion exhaust and secondary organics formed by photo-chemistry). In many urban and nonurban areas, these can be abundantly obtained after sulphates. Characteristics of particle emissions vary with the source and a host of other factors. Primary particles from natural sources tend to be coarse. About 50 percent are larger than 10 μm. Particles from non-industrial fugitive sources such as unpaved roads and wind eroded farmland, are significant on a mass basis for example constituting an estimated 110 to 370 million metric tons a year in U.S.A.. However only about 20 percent of this particulate mass is less than 1 um in size. On

the other hand most particles emitted by stationary and transportation sources are less than 2.5 μm in diameter. In addition the variety of different toxic elements found in fine material from stationary sources tend to exceed that typically found in emissions from man made or natural fugitive sources.

Techniques of Measuring Particulate Matter

Although various techniques are available to collect and differentiate the size and the quality of particulate matter, the ambient air monitoring methods adapt mass concentration methods and are widely used in relating epidemiological data. These techniquies, in fact do not really consider the physical size of the particles because of complexity of the task involved. However, they consider the aero-dynamic size simplification methods wherein the particles can be differentiated based on aerodynamic diameters. These, however are useful to determine deposition patterns of particles in the human respiratory system. High volume samplers (also widely used in sampling ambient air in Bangalore) with selective inlets, dichotomous samplers, cascade impactors, and cyclone samplers are the most commonly used devises with specifically designed collection characteristics.

A high volume sampler collects particles on a glass-fibre filter by drawing air through the filter at a flow rate of approximately 1.5 m^3/min, thus sampling a higher volume of air per unit of time. It actually measures "total suspended particulate matter" (TSP). Recent evaluations show that the high volume sampler has cut points of approximately equivalent of 25 μm

at a wind speed of 24 kph and 45 μm at 2 kph. Since the day to day variability in wind speed is within 10 percent, the methods produce highly reproducible samples.

One of the earliest analytical techniques other than TSP was the British Smokeshade (BS) method. It shows more sensitive relationship to carbon concentration than mass (Baily and Clayton, 1980). A similar method adapted in many American cities for routine monitoring is AISI light transmittence method. The aerodynamic size cut off points in AISI method is approximately 5 μm and in BS method is 4.5 μm respectively. It is important to note that the diameters of particles monitored in TSP methods are considerably larger and therefore intercomparisons and conversions among TSP, BS and AISI are severely limited. One exception appears to be the relationship between BS and TSP observed during sever London air pollution episodes when low wind speed conditions resulted in settling out of larger coarse-mode (Stilland et al, 1979) particles. (It is not out of point to indicate at this juncture that the wind speeds through out the different seasons in Bangalore city are considerably low except perhaps in the months of June and July i.e., begining of monsoon. The settling down of larger particles is high and therfore the TSP measures adapted widely in the city are quite related to smoke concentrations or BS measures).

The ambient air monitors are designed to measure pollutant concentrations at fixed locations. Most individuals in our society are highly mobile and therefore, personal samplers adapting the techniques of air sampling similar to those

mentioned above are used. Often, such studies involving fixed location monitors derive the differences between pollutant concentrations as indoor and outdoor and use mathematical ventilation models to estimate the total exposures. From an epidemiological point of view the dose response relationships are better obtained through the measurements of total exposures. The major assumptions behind these approximations are that the methods are comparitively less cumbersome and can be related to dosage concepts of biological intake. In order to derive these estimates it is essential to plan a proper survey so as to take care of multiple factors (Ellison and Waller, 1978) such as differences in cooking fuel, housing inequalities, tobacco smoking and occupational exposures.

Biological Intake of Particulate Matter and Health Impact

The biological intake of particulate matter composition is a very complicated mechanism. Much of this information is derived from toxicological studies of animals, clinical studies of humans and epidemiological studies from various researchers. It begins with respiratory tract deposition and pulmonary intake. Normally, the airborne suspensions that enter through respiratory system may either get deposited on the air way surfaces, or may be tranferred to unexhaled air and the remainder is inhaled. The mechanism involved in deposition are affected by physical and chemical properties including particle size distribution, density, shape, surface area, electrostatic charge, hygroscopicity or deliquescence, chemical composition, gas diffusivity, and related

properties. For a complete treatment and discourse, the EPA documents on "Air Quality Criteria for Particulate Matter and Sulphur Oxides, 1983, vol.3 (11) can be referred.

There are three important regions in respiratory system which are functional during deposition and absorption of particles. They are: (i) extra-thoracic (ET), (ii) tracheo-bronchial (TB), and (iii) pulmonary (P). The first one is often treated as upper respiratory and (ii) and (iii) as lower respiratory regions respectively. Generally, between 10 and 20 percent of inhaled particles are deposited in the pulmonary region. But, through mouth breathing, particles of 1 to 4 μm diameter cause pulmonary deposition upto 20 to 70 percent. However, only about 10 to 30 percent particles as large as 8 to 9 μm are deposited in the pulmonary region. It can be mentioned here that considerably large depositions in normal subjects are cleared from respiratory tract through the physiological mechanisms of mucociliary actions, sneezing, and coughing. But, persons with asthma, chronic bronchitis show excess tracheo-bronchial depositions. Children are usually more suspectible to such depositions compared to adults.

In general, the population groups at special risk to air pollution include young, the elderly, and individuals predisposed by some particular diseases such as asthma, bronchitis, cystic fibrosis, emphysema and cardio-vascular disease. In the normal population there are also non-diseased but hyper-sensitive individuals. Such nondiseased "hyper reactors" have been found

among at least three of the distinct population groups (normal, chronic bronchitic, and asthmatic) that have been evaluated under controlled exposure conditions in regard to their responses to SO2 and particulate matter (Lawther, 1955; Frank et al 1964, Nadel et al 1965, Burton et al 1969, Lawther et al 1975, Jaegar et al 1979, Sheppard et al 1980, 1981; Staly et al 1981). Much of this information is obtained from controlled studies which cover reversible and relatively less harmful conditions in humans. But, in actual epidemiological surveys exposure levels are higher. The symptoms, signs and diseases are quite unreversible and harmful to the extent leading to fatal hazards. Such exposure effects have been discussed in subsequent sections under acute and chronic exposures.

Nature and Impact of Sulphur Dioxide On Human Health

Of the four known gas-phase Sulphur oxides (Sulphur monoxide, Sulphur dioxide, Sulphur trioxide, and disulphur monoxide) only Sulphur dioxide occurs at significant concentrations in the atmosphere. A colourless gas with pungent odour, Sulphur dioxide is emitted from combustion of fossil fuels, such as coal and oil, as well as from many other sources.

Attached with SO2 emissions which cause pollution is the formation of acidic sulphates and their dissolution in rain drops. More often, the acidic sulphates remain in fine particle mode and are deposited in the respiratory tracts of humans. Further, Sulphur dioxide is very soluble in water and, when inhaled nasally, is readily (95 to 99 percent) absorbed on the moist

surfaces of the nose and upper respiratory passages (Frank et al, 1973). This may protect individuals breathing nasally at rest from even relatively high levels of SO2 exposure. It is indicated that at some level of ventilation, breathing shifts from nasal to oronasal (Niinimaa et al 1980), thereby increasing the dose of SO2 reaching the tracheo-bronchial (TB) region of the lung and probably leading to enhanced SO2 effects.

Sulphur dioxide has been found to affect a variety of physiological functions. These include sensory processes, subjective perceptions irritative or painful SO2 effects, and more objectively measured changes in respiratory function parameters. Of much more concern are cardio-vascular or respiratory effects found to be associated with exposure to SO2. It is to be mentioned here that there are consistent observations by many researchers (Frank et al, 1962, 1964; Nakamura 1964, Speizer and Frank 1966) as to the effects of pulmonary flow resistance or broncho-constriction in normal subjects at the level of 5 ppm (13.1 mg/m3). Only Andur et al (1953) have reported observations of significant cardio-respiratory effects on healthy adults at rest following SO2 exposures below 5 ppm (13.1 mg/m3) including exposures as low as 1 ppm (2.6 mg/m3). Other investigators (e.g., Lawther, 1955; Frank et al, 1962) have not observed similar results. Wide-ranging effects have been observed in subjects engaged in activities such as exercises where oral breathing takes place.

In attempting to define population at special risk for SO2 effects, Weir and Bromberg (1972) and Reichal (1972) exposed

patients with obstructive pulmonary disease to SO2 levels across the range of 0.3 to 4.0 ppm (0.8 to 10.5 mg/m3) and observed no statistically significant increase in air-way resistance or other pulmonary function effects. Studies reported by Jaegar et al (1979), Sheppard et al (1980) indicate that asthmatic subjects are susceptible to exposures at the lower ranges of an order of magnitude more sensitive than normal. Other than these pulmonary changes and associated symptomatic effects (such as coughing, wheezing, and dyspnoea or shortness of breath) in sensitive population groups, a combined effect with particulate matter especially hygroscopic salts have been studied by various authors (McJilton et al, 1973; Snell and Luchsinger, 1969).

In addition to Sulphuric acid and Sulphates which are shown to have similar effects on lung function as Sulphur dioxide, other non-sulphur particulate matters exist in ambient air. These include polycyclic organic matter (POM), lead, arsenic, selenium, ammonium salts and carbon as dust. Although controlled human exposure to some of these inherently toxic compounds is forbidden for obvious reasons, several investigators have conducted clinical studies using carbon and other inert particles. It is however, important to note that during historical episodes of air pollution, there are sufficient evidences to show that the smoke density in urban atmospheres invariably are associated with high sulphur dioxide pollution.

Nature and Impact of Oxides of Nitrogen On Human Health

The oxides of Nitrogen present in the atmosphere are

Nitrous oxide (N2O), Nitric Oxide (NO), and Nitrogen dioxide (NO2). In addition, Nitrous and Nitric acids have been found, free, or in the form of their salts. Nitrous oxide (N2O) is present as a regular atmospheric component at concentrations of the order of 0.5 ppm (Miller, 1958; Adel, 1951). Its stability makes it appear unlikely to play an important role in low level atmospheric reactions. The higher oxides of Nitrogen are formed in chemical processes such as nitrations, but by far the largest contributor is combustion at high temperature (auto-exhaust), whereby Nitric oxide is formed. At equilibium conditions most of the NO is oxidised to NO2. At a concentration of 1000 ppm, colourless NO is seen to turn brown with the formation of NO2, in a matter of seconds. However, at low temperatures the reaction is slower and Ozone oxidises Nitric oxides rapidly which subsequently, gets hydrated to form Nitric acid. Eventually, these are removed from atmosphere as rain droplets (Miller, 1958).

An interesting example of a large scale oxidation process, with Nitrogen dioxide was first observed in Los Angeles. The result is known as "photochemical fog", a phenomenon accompanied by eye irritation, plant damage, haze, Ozone formation and a characteristic odour. In urban conditions, at the time of minimal activity, concentrations of primary contaminants _ Carbon monoxide, Nitric oxide, Hydro-carbons _ increase slowly, in the absence of wind. The secondary contaminants, Ozone and Nitrogen dioxide, remain at negligible levels in the absence of photochemical reactions. The rising of the Sun and the burgeoning

of morning traffic speed the accumulation of raw materials, thereby Nitrogen dioxide begins to be generated at a substantial rate (Stern, 1968). It is to be noted here that neither starting products nor end products such as acids show eye-irritating effects as shown in "fumigation experiments" and therefore, intermediary oxidation products (and presence of formaldehyde, acroleum, peroxyacyl nitrate) are suspects as eye-irritants. Further, much of physiological reactions (lachrymation specially) is associated with the presence of aerosols, 'smog' formation by auto-exhausts and Sulphur dioxide.

Fairly large exposures to nitrogen dioxide have been induced on experimental subjects without any marked change in ventilatory tests (Hine et al, 1961). However, when occupational exposure occurs to this substance, effects are often delayed and persistent (Becklake, 1957). Nitrogen dioxide and ozone are relatively insoluble gases. They have their major biological reactions within the alveoli and may cause pulmonary oedema. Oedema or swelling at the level of the alveoli tends to increase the difficulty encountered by gases diffusing from the alveoli into the blood.

2.2.2 AIR POLLUTION EPISODES AND ACUTE EXPOSURE STUDIES

In section 2.2.1, the pollutants especially with respect to their nature and health effects as observed in semi-controlled and controlled conditions were described. It was also stated that in actual life conditions there would be diversified combinations of pollutants and their kinds of exposures. A brief

summary of the same has been attempted in this and the next section in order to comprehend the field data. This summary emphasises more upon particulate matter and SO_2 with possible information on other pollutant types (NOx, CO and others).

In the past five decades, human civilization has witnessed several air pollution episodes in several cities all over the world. The earliest available documentation of episodes described an incidence during 1930 in Meuse valley of Belgium. Dense fog covered the valley from Liege to Huy (Firket, 1931, 1936) from December 1 to 5, 1930. Approximately 6000 residents became ill and 60 deaths associated with fog occurred on December 4-5. People who died were sick only a short time and the onset of acute illnesses abated rapidly when the fog dispersed. The death rate in the area was 10.5 times normal.

In Donora, Pennsylvania (Shrank et al, 1949) a similar event occured during October 1948, which adversely affected 43 percent of a population of approximately 10,000 people. Twenty persons, mostly adults with pre-existing cardio-pulmonary diseases died during or shortly after the fog due to cardio-respiratory causes; and 10 percent of the population was classified as being severely affected. No records on pollutant concentrations in dense fog are available immediatly. However, in the follow up study daily averages of 0.4 ppm (approximatly 1140 $\mu g/m^3$) SO_2were recorded (Ciocco and Thompson, 1961) with increased mortality rates and morbidity effects (e.g., heart disease, and chronic bronchitis). Thus, these records raised the possibility of association between particulate matter in conjuction with SO_2

and acute health effects. But it was not until the effects of air pollution on major cities were identified, i.e., in London between 1948 and 1962 (Ministry of Health, 1954; Scott, 1953; Logan, 1953; Wilkins, 1954; Hewitt, 1956; Gore and Shaddick, 1958; Burges and Shaddick, 1959; Martin and Bradley, 1960; Clifton et al, 1960; Lawther, 1963), and in Newyork city (McCarroll and Greenburg et al 1962, 1967; Glasser et al 1967) that control efforts were taken seriously (Bradley, 1966).

Following are certain notable observations for and against the "association" theory of episodes with pollution and health effects.

(i) The mortality rate, in common, is considered as an index of acute episode which perhaps, is not unique to air pollution alone. Undoubtedly, it is a better health index of a community. Secondly, the excess death rate is often difficult to be assigned to any single cause, and the confounding occurs in majority of cases.

(ii) The acute fog concentrations lasting for 24 hours to one week period in majority of episodes are found invariably, associated with high particulate concentration of 1000 $\mu g/m^3$ (or smoke density of 10 COH) along with high SO_2. Other pollutants like NOx and CO with anti-cyclonic factors such as low wind speed, higher humidity and low ambient temperatures seem to have prevailed during the episodes.

(iii) Lipfert (1985) while analysing the excess death rates and pollutant concentrations especially the particulate

matter and/ or smoke density from the episodes and time series studies demonstrated consistent statistical associations between the two. Some similar associations were also noticed with SO_2 especially during the London episode. Accordingly, the time series co-efficients ranged between 0.6 % and 3 % excess mortality per COH unit (roughly equivalent of 100 $\mu g/m^3$ of TSP). They are also consistent with a multiple regression analysis of the episodes, which found a co-efficient of 1.1 % excess mortality per COH unit (Lipfert, 1980). Often, such findings were referred to as only "the timing of death" (Tukey, 1978). They also indicate a likely risk factor of an average of less than one excess death per one million population at the current TSP standard (i.e., 260 $\mu g/m^3$ for 24 hours) in the United States.

(iv) An important controversy against this most accepted theory of risk factor is certain inconsistency in the results found during New York city air pollution episodes. Glasser et al (1967) could not find marked increase in mortality rates during November-December, 1962 episodes although particulate matter exceeded 5.0 to 6.0 COH units and SO_2 peaked at the rate of 0.4 and 0.5 ppm or 1080 to 1310 $\mu g/m^3$ of ambient air. They however, noticed significant levels of complaints due to upper respiratory infestations. In contrast Glasser et al (1967), from January 29 and February 12, 1963 Newyork episodes indicated significantly high rate of morbidity and mortality among older age groups (45 to 65 and above 65 years) while TSP and SO_2 peaks in ambient air. Such inconsistancies were questioned by Cassell et al (1968) with particualr reference to Newyork city episodes.

(v) It can also be stated in conclusion from the litera-

ture that London episodes as stated above provide clear cut evidences for substantial increases in excess mortality at ambient levels of 1000 $\mu g/m^3$ TSP and almost the same level in SO_2. Certain New York city studies also tentatively stand by these associations. Among the four cities (Meuse valley, Donora, London and Newyork) and their episodes, perhaps most striking are the lower estimates of excess death rates at New York (at most 4 % to 20 %) compared to the 15 to 350 percents in London episodes and even larger increases at Donora and Meuse valley. The explanations given in literature are amply justifiable. These can be listed as under:

(i) Differences in specific chemical composition of pollutant mix,

(ii) Extremely dense fog with potentially high toxic forms in Meuse valley and Donora,

(iii) Continuous exposures of New York city population to elevated pollutant levels masking the effects.

Item (iii) above has much wider implications from the point of prescribing a standard upper limit which has been referred in section 2.3. It is worthwhile noting at this point that from the episode data on pollutant concentrations the acute exposures can be clearly delineated from chronic exposures by ascertaining not only the intensity of exposure but also by duration of previous exposure. It is often difficult to accept the common threshold limits for differenciating acute and chronic exposure effects in subjects with repeated and continuous (between weeks) exposures to very high concentrations as noticed

during New York city episodes. In contrast, high pollution levels persisted for several (approximately 4) successive days during Meuse valley, Donora and London episodes eliciting excess death rates and morbidity because of very high concentrations of smoke density and SO_2.

2.2.3 AIR POLLUTION IMPACT DUE TO CHRONIC EXPOSURES

Included in this section are the studies related to long term mortality / morbidity and cross sectional geographic studies pertaining to air pollution. Unlike episodes which are clearly delineated because of sudden increase in ambient pollution, the long term studies are complicated by multiple factors governing the issues of health effects. They are classified as chronic exposure studies. Literature abounds with such studies (Evans et al, 1984) where out-door environmental exposures (lowest-to-highest) are quantified and analysed for association either with mortality or morbidity rates. Many of these attempt include potential effects due to such confounding factors as cigerette smoking, occupation, social status, or mobility differences between areas. Because of methodological problems accurate characterisation of any quantitative relationship between health impact and air pollution parameters are not clearly achieved.

There are, infact, great variations among regression coefficients (Lipfert, 1985) of pollution (e.g., percent excess death rates per unit of pollutant) from among these studies (Gregor, 1977; Kitagawa and Hausen, 1973; Lave and Seskin, 1978;

Lipfert, 1978; Crochen et al, 1979; Mendelsohn and Orcott, 1979; Lipfert, 1984; Chappie and Lave, 1982; Gottinger, 1983). Such a trend is also recorded in case of morbidity impact. At the most, perhaps, the qualititive links are indicated , suggesting scope for evolving better analytic techniques and methods. The confounding factors, often influence air pollution impact through several ways and means (multi co-linearity, spatial auto-correlation). For example, cigerette smoking is a prime candidate variable for co-linearity considerations because it damages the same organs as air pollution.

In general, chronic exposure studies (epidemiological) employ two approaches to the analysis of health effects:

(i) Aggregation of population groups from a single study on the basis of mortality/ morbidity and other information, e.g., smoking, or socio-economic status data,

(ii) Aggregation of similar data for entire populations across large geographical areas e.g., cities, counties, or standard metropolitan statistical areas (SMSAs).

(Preferably, they also employ aerometric data from among a network of monitoring stations, thereby categorising geographical areas as "low" to "high" air pollution areas.)

Some serious criticisms and drawbacks of such approaches and incumbent results can be listed as below:

(i) Use of retrospective air quality areas or zones to compare and elicit differences in health impacts, assuming similar gradients of exposures,

(ii) Inadequate controls for possible age and such other

personal charecterestics among population groups,

(iii) Lack of information on lifetime (including occupational) exposures to pollutants such as particulate matter or SO_2,

(iv) Failure to correct for smoking habits, ethnic background, genetic heredity, dietary patterns, occupational exposure patterns, or other regional factors of life style,

(v) Unjustifiable and imprecise qualitative estimates of particulate pollution and ambiguities regarding locations of sampling devices in relation to study populations, therefore, raising questions about the representativeness of the aerometric data in estimating exposure levels,

(vi) Finally, numerous internal inconsistencies in their reputed results which neither support nor contradict their conclusions.

Inspite of above listed drawbacks certain implications of the results can be certainly taken note off. For exammple, The acute exposures as dealt in the previous section remain a basis for accepting the pollution impact more or less unreservedly. This information has deep roots of impacts even into the chronic exposures. Lave and Seskin (1972, 1977) through studies among 117 U.S SMSAs state that for every 10 % of change (increase or decrease) in Sulphate or TSP air pollution level there would be a resulting change in total mortality rate of 0.50 % (for Sulphur) and 0.44 % (for TSP); in otherwords, decreases of 5 and 4 persons deaths per 100,000 could be expected for every 10 percent reduction in ambient air sulphates or TSP concentrations

respectively. Further studies indicating strong, consistent positive associations really conclude that stringent abatement of sulphur oxides and particulate matter would produce social benefits (based on health effects alone) that greatly exceed social costs.

2.3 ACUTE AND CHRONIC EXPOSURES AS BASIS OF PERMISSIBLE UPPER LIMITS AND STANDARDS

Much of the information on acute and chronic exposure effects emerge out of insufficient epidemiological data available during and after the episodes. In spite of this, they are the best sources of information used in evaluating the ambient conditions elsewhere.

2.3.1 RED LINE MAXIMUM AND PEAK EXPOSURE LIMITS

It is widely accepted that increase in mortality occurs when either particulate matter or Sulphur oxides (smoke density) levels increase beyond 24-hr levels of 1000 $\mu g/m^3$ (The EPA criteria document, 1985; Lipfert, 1985). Such increase in mortality, mainly in the elderly or chronically ill, might logically be attributed in part to even brief exposure to very high short-term peak (hourly) levels in the pollutants. The available information on episodes establish marked increases in mortality and morbidity being associated with prolonged elevations of particulate matter and sulphur dioxide levels of 1000 $\mu g/m^3$. This is especially so in the presence of humidity (fog) for several days without intermittent relief or return to near normal

levels. It is to be noted that mortality need not be expected to occur regularly as a function of short-term peak excursions of 24-hour particulate matter or SO_2 levels above 1000 $\mu g/m^3$. This view, is supported by epidemiological literature, wherein mortality were found to occur on various scattered days when particulates and Sulphur dioxide levels reached comparably high (more than 1000 $\mu g/m^3$) 24 hour levels as on other days (or sets of successive days) when mortality clearly increased.

2.3.2 IMPERFECT GREEN LINE EXPOSURE LIMITS

The acute conditions below 1000 $\mu g/^3$ for 24 hour prolonged period and their association with mortality and morbidity presents diversified views among the expert groups. First of all there seems to be no clear "threshold" values emerging out of epidemiological literature. Available information suggests that small but significant increases in mortality (1 % excess death rate per 100 every raise of $\mu g/m^3$, Lipfert, 1985) and morbidity (approximately 5 % to 10 % excess) have been noticed at levels ranging between 500 - 1000 $\mu g/m^3$ of smoke related particulate matter concentrations (Martin and Bradley, 1960; Martin, 1964; Ware et al, 1981, Mazumdar et al, 1981; and Lather et al, 1970).

Further, diversified views by experts have been expressed as far as chemical properties of particulate matter (not much detais are presented) in the events of episodic exposures are concerned.

It is important to note that the permissible limits of

human exposures in various countries are considered on the basis of some fractions of acute and chronic episode levels. (The prescribed standards for SPM, SO_2, NOx in India are shown in table 3.3, Chapter 3) There can be other superseding criteria (like economic conditions) in the region which might perhaps deprive the strict adherance to health criteria.

The epidemiological studies with reference to chronic exposures indicate general decrement in lung functions among adults (Ferris et al, 1973, 1976) and respiratory effects in children (Lunn et al 1967). The levels of particulate matter ascribed to these are the annual averages of 200 to 300 micro-gm per cubic meter.

Impairment of pulmonary function is likely to be one of the effects of exposure to air pollution, since pulmonary system includes tissues that receive the initial impact when toxic materials are inhaled. Acute and impairments chronic in function may be significant biological responses to air pollution episodes.

RESEARCH DESIGN AND METHODS

CHAPTER 3

RESEARCH DESIGN AND METHODS

3.0 STRUCTURE AND SCOPE OF THE PRESENT RESEARCH DESIGN

The present research design is envisaged through a two stage data gathering procedure and analysis in order to understand the problems of air quality in relation to general health morbidity in the city of Bangalore. The two stages are described below:

Stage 1: (i)The steps are to collect retrospective data on air pollution over the city areas and population growth in them, (ii) to analyse the pollution trends and seasonalities to ascertain the air quality status in the immediate past and (iii) to analyse the population density data in conjunction with the pollution data to identify high pollution risk population areas.

Stage 2: (i) The major task is to carry out a prospective air quality as well as epidemiological study by suitably sampling the air and population in the "high risk" area identified in stage 1. The air pollution study is to be carried out over a period of one year, and two morbidity checks are to be carried out on the same sample population at the begining and end of the year during which the air quality study is carried out.

The above procedure was evolved through an analysis of Stage 1 study. Since the population samples are exposed to varied micro-climatic and activity based environments, a weighted exposure estimate of individual subjects was thought appropriate for final evaluation. These estimates are determined empirically

by using the information generated in retrospective analysis and actual data gathered from the households.

In brief, the two sets of investigations are planned to evolve the difference in health conditions (change in morbidity) incidental during the period of one year and observe associations of this change with that of cumultive pollution-exposures in the intervening period.

3.1 STAGE 1. AMBIENT AIR QUALITY ASSESSMENT

3.1.1 RETROSPECTIVE DATA COLLECTION PROCEDURE ADOPTED TO ASSESS THE AIR QUALITY STATUS

An extensive search was made to gather past air quality data from other organisations before the research team presented the "two-stage research design" to a working group constituted to appraise and advice on the study in the early part of 1988. Various research organisations, governmental agencies and research literature were consulted. Finally, extensive data gathered from two organisations were selected for analysis comprising of a period of eight years (1980-1987) which however, was extended till the end of stage 2 (1988-1989) study for the sake of updating the information.

In the retrospective study, the type of data analysed were the actual monitored levels of ambient pollutants from among various stations located for the purpose. This task of monitoring was done by (i) the Regional Occupational Health Centre (ICMR, Bangalore Branch) during 1980 to 1984, and (ii) the Karnataka State Pollution Control Board from 1985 to 1989. In the

present study the two periods have been referred to as Phase I and Phase II periods for convenience and continuity in analysis.

It can be mentioned here that the location of monitoring stations in both phases are similar except perhaps in their protocol of data gathering. In all, the two phases identify three regions of pollution zones in the city which show predominance in public activity such as (i) a centrally located commercial zone, (ii) a residential zone surrounding the commercial and (iii) an industrial zone located at the outskirts. It is apparent that these zones have actually a combination of all three activities together in varied proportions. The monitored levels are assumed to be the representative values of predominant pollution sources in the concerned area. The Phase I had a network of 32 stations in all, whereas Phase II had only ten representing the three pollution zones.

The major pollutants monitored in both phases are:

(a) Airborne Suspended Particulate Matter (SPM),

(b) Oxides of Nitrogen (NOx),

(c) Sulphur dioxide (SO_2).

The concentrations of these pollutants in ambient air had been measured only during the day time (8 hr) and expressed in terms of micro-gram per cubic meter of air (µg/m3). The equipments used are the high volume samplers (APM 410 and 411; ENVIROTECH, See the photo figures 1 and 2) which filter the ambient air at a rate 1 to 1.5 liters per minute. Analysis of the gaseous pollutants were done by standard chemical methods using

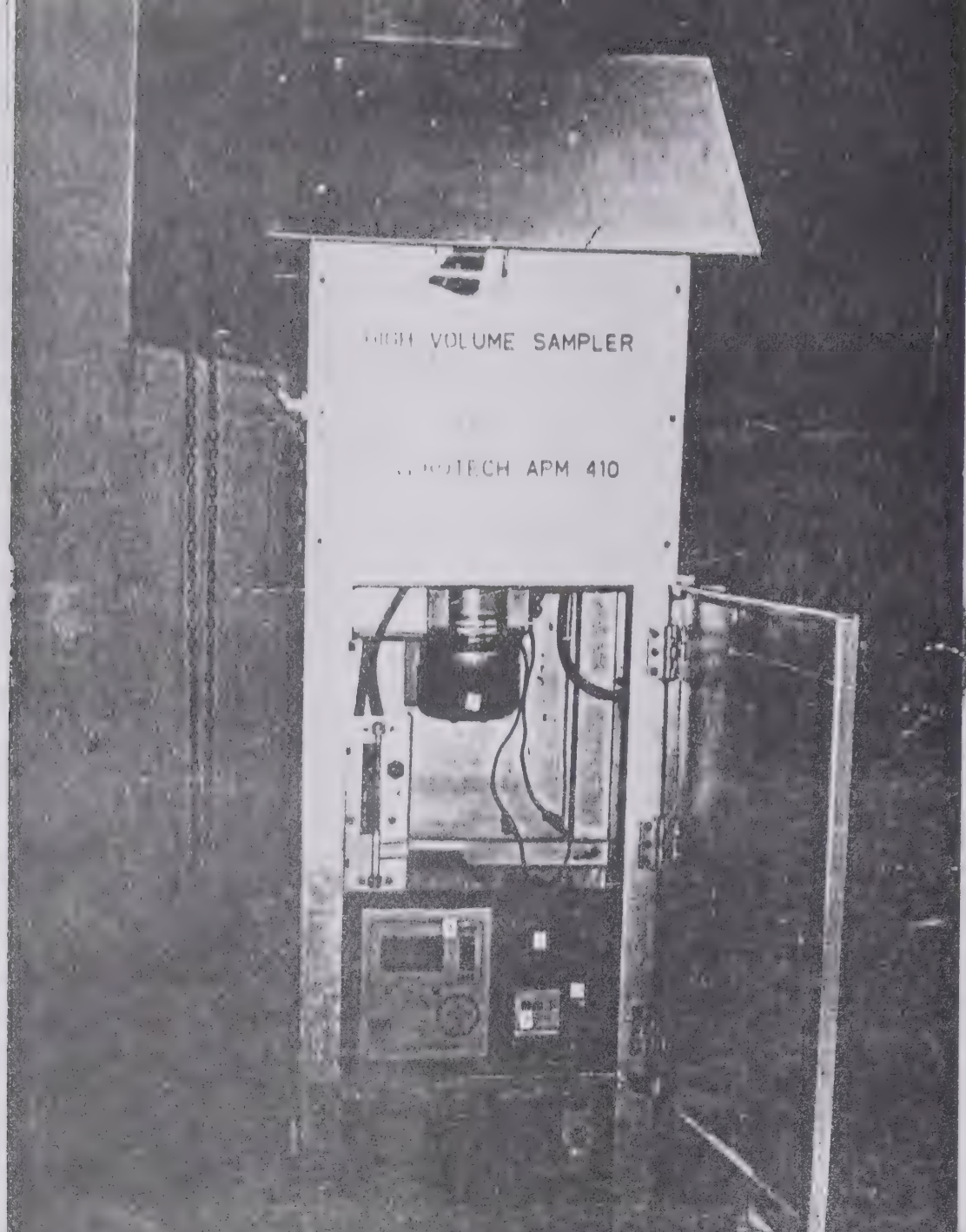
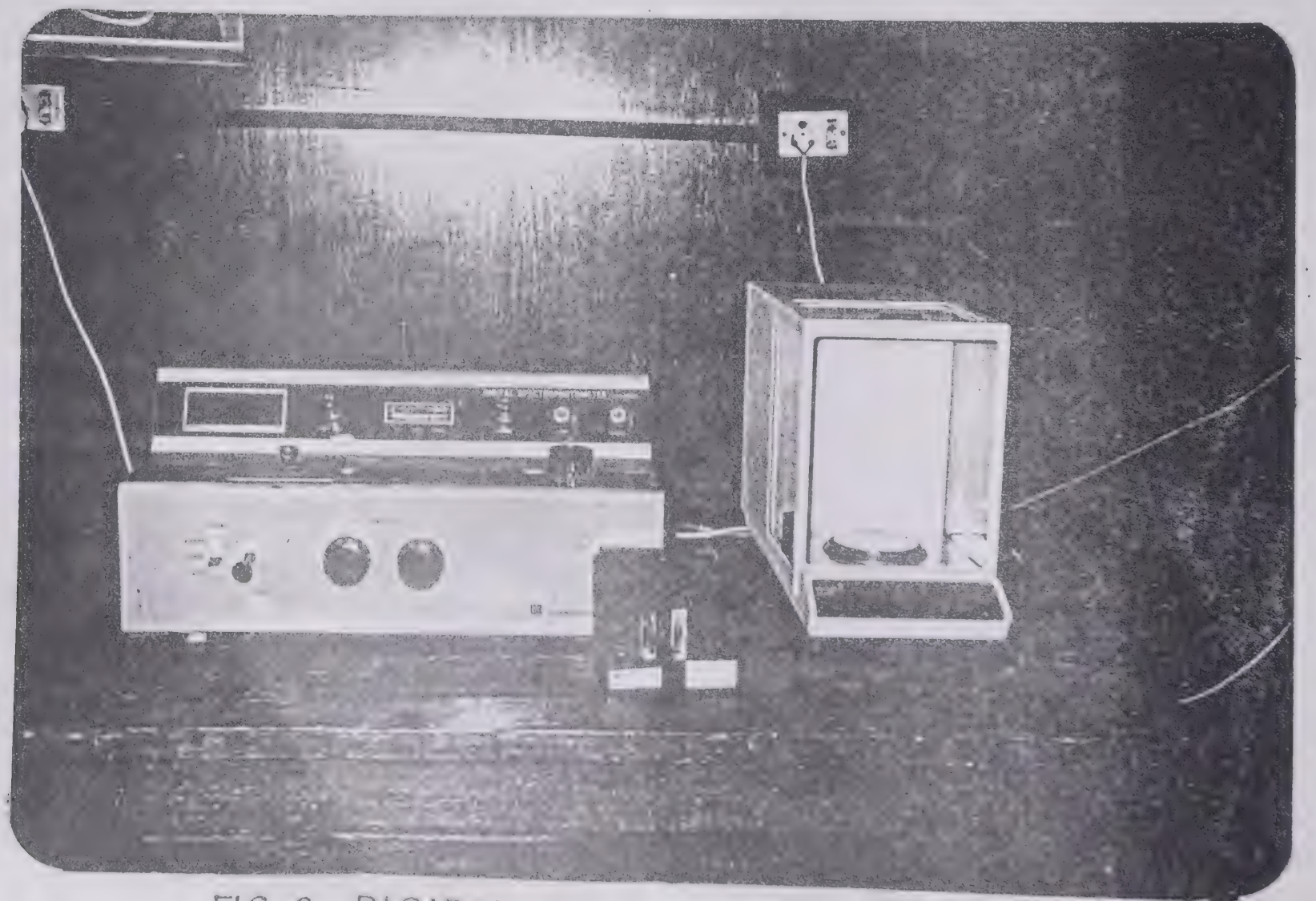


FIG.1 HIGH VOLUME SAMPLER.



spectrometric techniques. In case of Phase I study, the monitoring was done on fortnightly basis, whereas in Phase II on a weekly basis. There were some sporadic attempts to check the pollution levels during night times and also for other pollutants such as Hydrogen Sulphide, Oxidants and Lead.

Considering the reliability and feasibility of utilizing the monitored levels of pollutants and to arrive at an overall picture of the prevailing air quality situation in the city, two sets of specific analyses are carried out. They are:

(i) the determination of spatial distribution pattern of pollutants prevailing at various parts of the city, and

(ii) the determination of seasonality distribution pattern of these pollutants.

Data gathered in Phase I study fulfilled only the first objective, because the number stations located were more during this phase covering a widespread area. However, due to lack of continuity in the data gathered from within the stations the same could not be used for generating seasonality characteristics. Phase II study fulfilled both the objectives reasonably well and so, data from this phase (KSPCB) are used to generate spatial and seasonality characteristics. Further details are described below:

3.1.2 DERIVATION OF SPATIAL DISTRIBUTION PATTERNS

The yearly mean, standard deviations, minimum and maximum concentration of pollutants from the records for each of the

monitoring stations from Phase I and Phase II studies were computed. These concentrations have been assumed to represent the ground level concentrations (GLC) entirely because of their location heights which fall within a range of 1 and 12 metres. Further the built-up area where population dwellings are situated in the corporation limits (140 square km.) of the city show an average altitude of 898.4 metres above MSL with a standard deviatio of 21.8 metres.

In fact the monitored concentrations are of an outcome of emissions from major sources operating within the region and are subjected to diffusion parameters such as ambient temperature, humidity, wind speed and direction prevailing within the physiological breathing zones of the population. Secondly, the aerial distances between the stations ranged between 0.75 and 1.5 kilometers thereby covering the entire region within the corporation limits reasonably.

The above mentioned features enabled to plot the location points of the stations on a map of Bangalore city and use the yearly mean concentrations of pollutants from these stations to derive the intervening levels through simple linear interpolation methods. This procedure is adopted for the years comprising the Phase I study and later, for each year from the Phase II study separately, thereby arriving at isolines showing the air quality status of different parts of the city. The same have been presented in Chapter 4 during the analysis of air quality status prevailing in the city.

3.1.3 DETERMINATION OF THE SEASONALITY PATTERNS

The pollutant concentrations obtained from various stations in Phase II study were pooled separately based on two categories of zones viz., "high and moderate pollution" zones. This information was generated through an evaluation of various areas and the pollutant concentrations with respect to the prescibed permissible limits. The pooled concentrations were also statistically tested for actual differences between the stations and for non-compliance with the standards.

The data from the stations present within the similar zones were pooled by monthly basis and the mean levels were computed. They were plotted as mean concentration versus time in months for the years 1985 to 1987. The monthly variation in pollutants, trend and seasonal indices were determined using the techniques of moving averages and smoothening of wide fluctuations (A standard computer program is used for this purpose). The results will be presented in Chapter 4.

3.1.4 EVALUATION OF THE SPATIAL DISTRIBUTION AND SEASONALITY PATTERNS OF POLLUTANTS

The above mentioned procedures were used in ascertaining the temporal distribution patterns of major pollutants in the city. At the same time, they were subjected to evaluation of air quality from the point of view of permissible standards. The standards prescribed by Central Board of Prevention and Control of pollution in India under the provisions of 1981-Air Act were used. According to these, prescribed limits for three areas such

as "sensitive, residential and mixed use" and the corresponding levels of SPM, SO_2, and NOx are shown in the table 3.1.

If in any zone the concentrations monitored at 8 and 24 hourly sampling periods exceed these standards, then they can be construed as high risk zones and call for abatement procedures. These norms were used in the present study to identify the zones exceeding the normal air quality limits as a criteria to select the population sample for conducting epidemiological investigations (Stage 2).

Further, the areas of high density popualtions were identified. The areas showing high pollution and high density of population were used for conducting epidemiological surveys as detailed in subsequent sections.

Table 3.1 Permissible Upper Limits of Pollutant Concentrations

(in micro gram per cubic metre of air)
(Source: 1981 - AIRACT)

Area	Averaging Time Eight Hour Standard			Averaging Time 24 Hour Standard		
	Spm	SO_2	NOx	Spm	SO_2	NOx
Sensitive	100	30	30	70	20	20
Residential	200	80	80	140	60	60
Industrial	500	120	120	360	80	90

3.2 STAGE 2. THE HEALTH IMPACT ASSESSMENT

It is important to indicate at this juncture that there was a simultaneous attempt made to gather morbidity and

mortality statistics corresponding to the time and locality in particular. This was tried through data gathering from among public and private hospitals and nursing homes in Bangalore. But the data maintained in hospitals generally suffered from serious drawbacks because of heterogeneous and incomplete patient records and mixing up of information from patients admitted to hospitals from outside Bangalore city. Further, the past records concerning city population were sporadic and were unsupplemented by systematic year to year changes in the patients' conditions. It became inevitable for venturing into the task of gathering health information from well identified zones and households in particular. This method required more of epidemiological type of data gathering procedures envisaged originally and systematic survey of pollution exposure information. The methods adopted are described below:

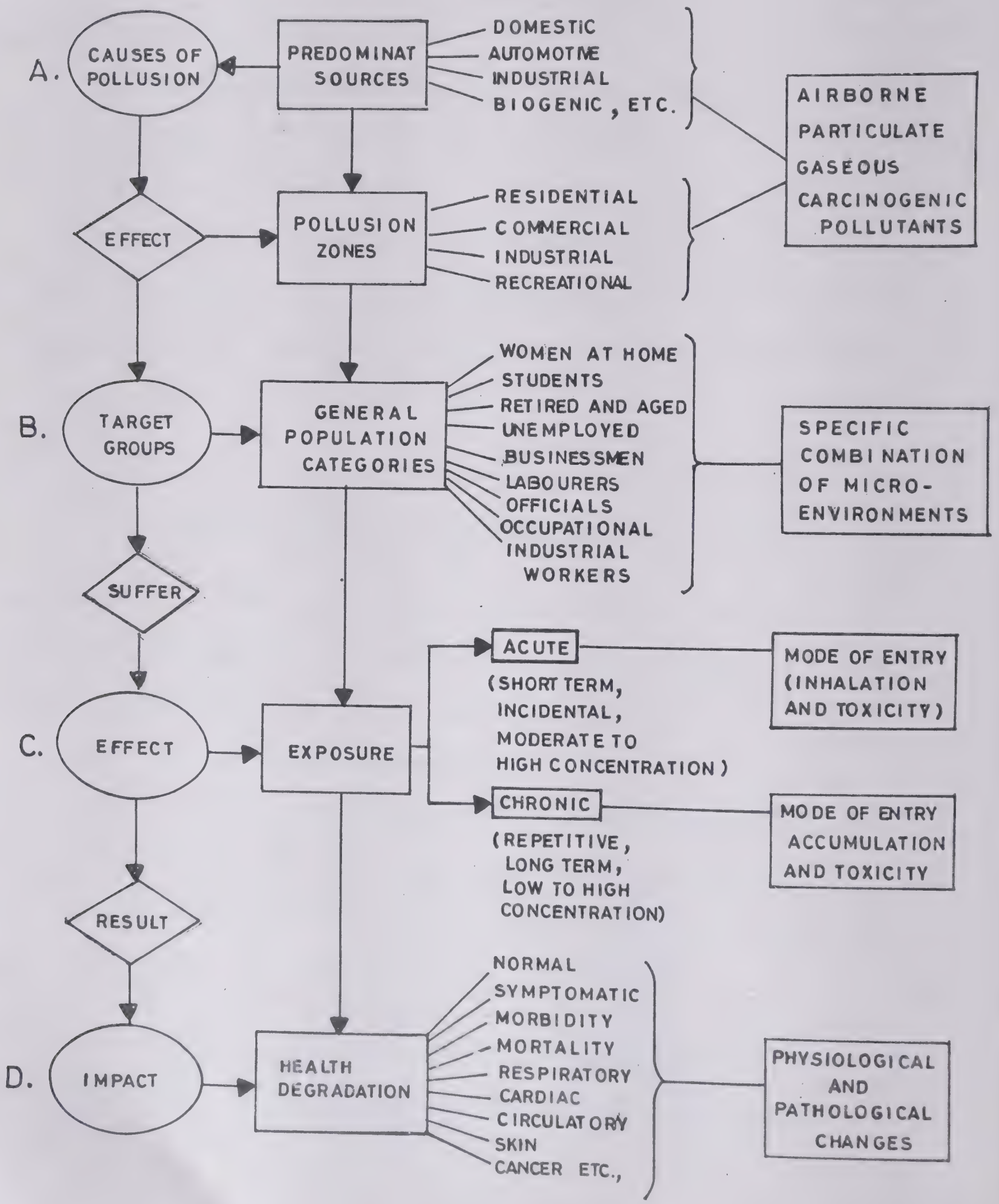
3.2.1 PROSPECTIVE EPIDEMIOLOGICAL INVESTIGATIONS

The general population categories, their location, mode and period of their activities through which exposure to pollutants occur, are shown in the schematic diagram in figure 3.1. In addition to this, it is hypothesised that the micro-environments created by population activity zones build up pollutant exposures in an integrated way. Such integrated exposures can be categorised in terms of acute and chronic exposures.

In the present investigations, it has been envisaged to conduct epidemiological studies among the population groups from

health impact due to pollution change. A two-time health study helps in estimating the changes in morbid conditions of the subjects, and their total pollution exposures prevailing during the intervening period.

Figure 3.1 Schematic diagram of a chain of accession points chosen for Stage 2 study



The schematic diagram as shown in FIG 3.1 attempts at describing a chain of accession points preferred to be identified for convenience and feasibity for data gathering and analysis. It also tries to bring together observations of a cause and impact association arising out of air pollution and consequent health changes from a typical prospective epidemiological survey point of view. The foremost task of identifying the zones of high pollution regions, population categories residing in the zones, likely pattern of their exposure estimates and changes in health conditions of samples are shown as A, B, C and D respectively.

It can be generally conceived that a person who resides at a particular zone of pollutant concentration traverses through other zones for the purpose of routine activities. Thus he or she gets exposed to various degrees of pollution prevelant in those zones. A sum total of these exposures weighted by activity durations constitute an integrated exposure estimate. The activities weightages obviously vary for different population categories. It is therefore felt necessary to generate this information instead of simply depending on ambient monitoring data. It is also assumed that the change in morbidity depends upon an accumulated and spurts of exposure constituents in reality. Keeping this in mind, the data gathering protocols are formulated as described below:

3.2.2 METHODS USED IN GATHERING HEALTH DATA

Based on the ambient air quality status prevailing in the city the population samples residing at two high pollution

zones are chosen at random for a two-time general health morbidity study separated by a period of one year. The areas chosen are

(i) Chamarajpet division, predominantly a residential zone,

(ii) Cottonpet division, predominantly a commercial zone.

A sample of 350 households comprising of nearly 1500 subjects is chosen for the health survey. The same population samples are also subjected to the determination of their exposures empirically. The association of pollution exposure and health degradation were planned to be examined in the final analysis of this data.

A team of doctors headed by a chief physician visited the households usually between 5 pm and 8 pm except during Sundays and festival holidays. The first health morbidity study was held during October and December 1988. The second survey was repeated in the same community with the same subjects during October and December 1989.

A standard protocol of general health survey was undertaken by the team doctors in the communities. The protocol is shown in Annexure 1. Medical symptoms, signs, personal and family histories of the subjects were recorded. Certain basic clinical examinations and tests were conducted in order to arrive at specific diagnosis for various diseases. It may not be out of place to mention here that the medical details of the subjects undergoing regular treatment as patients elsewhere from

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India

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established diagnosis and clinical tests were recorded from their medical documents in order to strengthen the diagnosis.

The above procedures were carried out during the two-time (1988 and 1989) epidemiological investigations. An opinion survey of the subjects and the doctors is undertaken so as to indicate the degree of change in health conditions during the second investigation (1989). A five point scale is used to ascertain the change. The degree of change were stated "as much better, same as before and much worse" with reference to last year's (1988) symptoms, signs and disease diagnosis. The diagnosis as obtained in these investigations are coded to comply with the International Classification of Diseases (ICD Manual, Ninth Revision, 1977). This enabled discarding disease enumerations other than inter-national standards.

These two surveys were carried out to establish the prevalence of health morbidity in the communities, and to generate the trasitional matrix for the disease dynamics as incidental between the intervening period of one year. The details of analysis of the same are described in a subsequent section.

3.2 Procedures used in generating integrated exposures for the sample population and pollutants in the present study

The regular ambient air monitoring held in Bangalore by the Karnataka State Pollution Control Board (KSPCB) at ten different stations spread over the various parts of the city are identified as one of the sources of data input. This information is suitably utilized while estimating outside residential exposure constituents required to generate an integrated exposure of individual subjects. Since the monitoring held by KSPCB is confined to only the day sampling of 8 hours, two other sampling stations were located at the place of health surveys to monitor the ambient pollutant concentrations. In the latter two the monitoring was held for 24 hr period in order to account for the total residential exposure of the communities. The total monitoring carried out in these stations during the prospective epidemiological survey was for 52 weeks. Alternating week days after each week were chosen for monitoring in order to obtain a randomised day sampling for the complete year.

An activity survey of the subjects was also held by recording the actual time spent by the subjects in various locations and activities such as

(i) stay at home,

(ii) travelling,

(iii) occupation,

(iv) shopping, recreation and miscellaneous activities.

Basically, two types of activities viz., indoor and

outdoor, were identified. The ambient concentration of pollutants as recorded from the closely situated monitoring stations were considered for estimating activity based outdoor exposures. The assumption was that air pollution concentrations were homogeneous both in space and time, within each micro-environment representing the specific activity of the subject. Since, in indoor activity, the internal sources of emissions such as combustion of fuels in cookstoves considerably influence the indoor air quality, a realistic "ventilation model" (Jones and Fagon, 1974) was used to estimate the exposure within the domestic micro-environment. An estimate of total exposure experienced by the subjects was obtained by integrating all the activity based exposures.

For example, the integrated exposure for an individual (i) was computed as sum of the product of the pollutant level in each micro-environment (j) and the time the individual is spent in the micro-environment:

$$E_i = \sum C_j \, t_{ij} \qquad \ldots \quad 1$$

where E_i = integrated exposure of an individual (i) over the time period

C_j = pollutant level experienced in activity based micro-environment (j),

t_{ij} = time spent by the individual (i) in micro-environment (j).

A standard proforma of questionaire as shown in Annexure

1 duely filled by the investigators through an interview held with the subjects at the time of house-hold visit, served the purpose of generating this information.

3.2.4 Ventilation Model and Residential (indoor) Exposure Estimate

Since the pollution is generated by a source (cook-stove and fuel combustion) indoor at the time of its activity, and the plume spreads exponentially thereby reaching a steady state due to ventilation of the micro-environment and outdoor concentration of pollutant type, a model (Jones and Fagon, 1974) incorporating ventilation factors is considered, which is as follows :

$$C_c = C_0 \exp(-St) + (C_0 + Q/VS)\,(1-\exp(-St)) \quad \ldots \quad 2$$

Where, C_0 and C_c are indoor concentrations of pollutants (in $\mu g/m^3$) at times t_0 and t_c respectively, i.e., before and during domestic cooking. C_0 is assumed to be equivalent of concentrations monitored at the ambient station in that locality at that time. Q is the quantity of pollutant generated inside the household, which in turn is calculated by

$$Q = Q_f \times E_m \quad \ldots \quad 3$$

Where,

Q_f is the quantity of fuel consumption for (a) fuel wood (kg per day), (b) kerosene (lit/day), (c) Liquified Petroleum Gas (g/day). Electricity emissions of the types considered in the present study are negligible.

Em is the rate of emissions of SPM, SO2 and NOx.

Following table shows the estimated emission rates for each fuel type: as obtained from literature (Kirk Smith et al 1986).

Table 3.2 Rates of emissions of combustion of different fuels (n = fuel efficiency)

STOVE TYPE	SPM	SO2	NOx
Firewood n = 40 %	15069.44 µg/kg	597.22 µg/kg	763.88 µg/kg
Kerosene n = 85 %	0.33 µg/lit	35.56 µg/lit	2.15 µg/lit
LPG n = 85 %	0.233 $\mu g/m^3$	negligible	1.26 $\mu g/m^3$

Further, V is the volume of household in m^3 and is obtained by the product of the floor area of household and height of ceiling. t is time elapsed during cooking activity, and S is the effective air exchange rate which is calculated as

$$S = K.F/V \qquad \ldots \quad 4$$

Where, K = the mixing factor (non dimentional), and it is assumed that for perfect mixing K = 1. However K usually lies between 0.1 and 0.4 in practice. (In the present study, the values of K were selected on the basis of a ratio between the actual volume of ventilation through ventilators and the inside total capacity of households)

F = the ventilation air flow rate (m^3/sec) and is given by the product of area of ventilation (m^2) and wind speed (m/sec).

Depending upon the the direction of wind flow with respect to ventilation, the angle (θ) of impact is determined.

$$F = \text{Cos}\theta \times A_v \times W_s \qquad \ldots \quad 5$$

It is assumed that Cos θ varies between 0 and 1 depending on the direction of flow and ventilation. It is treated as 1 in case of direction of flow becoming perpendicular to the ventilators and 0 in case of parallel flow. It is true that even the parallel flow allows for certain ventilation and therefore in the present situation Cos θ is treated at least equivalent to 15 degrees.

A_v is the area of ventilators (m^2) which in fact, is shared equally for inflow and outflow of air. The ventilators included the windows, doors and chimney having direct access outside the house.

W_s is the wind speed (m/sec) as recorded by the central observatories.

3.3. METHODS OF ANALYSIS : STAGE 2 STUDY

In Stage 1 study (sections 3.1.1 to 3.1.4), the interpolation methods used in determining ambient air quality with particular reference to spatial and seasonality distribution patterns were described.

In the following sections the methods of analysis used during Stage 2 study, i.e., (the prospective epidemiological study) are described. It comprises of two major components:

(i) Health morbidity statistics generated during two time (1988 and 1989) epidemiological survey particularly with reference to the samples of general population surveyed.,

(ii) Analysis of shifts or change in disease morbidity in relation to the cumulative influence of exposure during 52 weeks of intervening period.

3.3.1 Health Morbidity Statistics with reference to the samples surveyed

The following table shows the relevant information of the two divisions chosen for Stage 2 study from an epidemiological point of view.

DIVISION	Total Estimated Population (1988)	Area of division (sq.km)	No.of houses selected (1988)	(1989)	No. of subjects surveyed (1988)	(1989)
1.Chamarajpet	61,547	0.84	171	157	517	521
2.Cottonpet	65,500	0.80	183	195	622	726

The selection of the sample of populations among the divisions were done ramdomly. Due to practical problems of reaching the households at an appropriate time, some subjects were to be left out between the two field visits. However, all possible efforts were made during the subsequent visits in the

same locality to meet these in order to generate a cohesive set of data from the same subjects.

Due to certain practical reasons only the subjects of age above 10 years were consulted in each household and therefore, the morbidity statistics generated during the present study infact leaves behind a large number of infant and childrens' population. It may not be out of place to mention here that such field investigations would become successful only by special support and co-operation by the public concerned.

While analysing the morbidity data first two sets of tables for the years 1988 and 1989 are generated based upon a standard classification of normal subjects. Statistics like simple frequency and the percentage population were obtained for the two divisions separately for the sake of comparison.

A disease classification prioritising the respiratory, heart and circulatory types was considered important for the sake of appreciating the impact of air pollution especially due to airborne particulates, Sulphur dioxide and Oxides of Nitrogen. Further, the groups were compared with reference to the variations from the important characteristics arising out of individual and community factors.

Secondly, an analysis was made to show the number of subjects under each category exceeding the permissible standards of ambient exposure prescribed for the locality and pollutant type. A set of frequency and cumulative distribution charts of

sample population was generated for annual exposure concentrations. Subsequently the same is used in evaluating the risk proneness of the subjects for exceeding the permissible limits.

3.3.2 Analysis of Change in morbidity between the two Morbidity surveys (transitional disease states)

The two-time disease diagnosis data were coded in a standard format. Only the subjects complying with both surveys of accession were sorted and taken up for analysis. Considering 1988 as the base year and 1989 as the end year the distinct cases falling under various conditions were arranged in a systematic manner. Thus among the set of conditions that prevailed during the entire study, year 1988 data showed 87 types and 1989 data 135 types respectively (See Annexure II).

Further, the subjects suffering from just single diseases in both years are found to be 46 types and the rest had combination of diseases. In addition to these there were normal and symptomatic subjects in 1988, whereas in 1989 normal and mortality cases were also observed. The symptomatic subjects from the first study showing the same symptoms in 1989 also, were treated for final analysis as confirmed cases under specific disease diagnosis.

A final and simplified transition table depicting only 12 conditions and their transitions between 1988 and 1989 were chosen for analysis. This was generated on the basis of a

standard disease classification adopted to prioritise the exposure prone subjects which is listed below:

(0) Normal (NAD)

(1) Upper Respiratory Infestations (URI),

(2) Lower Respiratory Infestations (LRI),

(3) Cardiovascular (Circulatory) Diseases (CVS),

(4) Skin and Subcutaneous Diseases (SKIN),

(5) Diseases of Special Senses and Nervous System (CNS),

(6) Metabolic and Endocrine Diseases(MED),

(7) Infectious Diseases (ID),

(8) Gastro Intestinal and Digestive System Disease (GI),

(9) All others excluding 1 to 8 (AO).

(10) Combinations (1 to 9)

(11) Death or mortality

Accordingly, disease transition tables of frequencies and probabilities were generated. Certain projections were tried using "Markovian Analysis of Morbidity". Subsequently, grouping of data was done showing six types of transitions mainly. They are the subjects :

Group 1. Found "Normal (NAD) during both years"

Group 2. Suffering under "Same disease condition both years"

Group 3. Changing from an Higher order disease (D2) to the lower order disease (D1), i.e., (D2 to D1)

Group 4. Changing from Lower order disease (D1) to Higher order disease (D2), i.e., (D1 to D2)

Group 5. Change from Diseased to Normal

Group 6. Change from Normal to Diseased

These groups were further analysed for differences in variances observed in exposure characteristics and related factors as described in the subsequent section.

3.3.3 ANALYSIS OF ANNUAL AND CUMULATIVE WEEKLY EXPOSURES

The mathematical model and the procedure used for the purpose of estimating activity weighted exposure and integrated exposure were described in 3.2.3 and 3.2.4 in detail. In this section the methods used in generating similar exposures on weekly basis have been considered first. Secondly, the procedures used to derive exposure estimates closely identifying their nature such as acute and chronic are presented. These analyses procedures are developed using cumulative techniques as described below.

The variables cosidered for estimation of weekly integrated exposures (WIE) were:

(i) Suspended Particulate Matter concentrations as obtained in the weekly ambient monitoring procedure

(ii) Meteorological data such as wind velocity and its direction (only the mean of 7 days monitoring data, during the weeks 1 to 53 preceding the day of second medical visit),

(iii) Average time elapsed for various activities of individuals as obtained from the field survey proforma

(iv) Average fuel consumption from each household as obtained from the field survey proforma

(v) House-hold characteristics with respect to ventilation and diffusion of pollution.

The integrated exposures of individuals (Approximately equivalents of Total Personal Exposures) were estimated on weekly basis for one year. The weekly exposures thus generated, were represented by the typical days in the weeks of estimations but not all the days in the past year.

The cumulative frequency analysis techniques and charts were used to ascertain the percentage of the sample among the transition groups encountering various degrees of exposure in SPM. Both annual mean and cumulative of 52 weeks total exposures to SPM were used for this analysis. Subsequently, the cumulations of exposures above various permissible standards were tried and analysed for differences in exposure characteristics between the transition groups. It was hypothesised that the change in morbidity between the two points of time are likely to be associated cumulative influence of pollution concentrations prevailing during the intervening weeks. Here, the total cumulative exposures are treated as chronic exposures and those cumulations as above permissible standards are treated as acute exposures.

The results of the analysis will be presented in Chapter 4.

RESULTS AND ANALYSIS

CHAPTER 4

RESULTS AND ANALYSIS

The results and analysis of two stage air pollution exposure and health impact studies are presented in this chapter in accordance with the procedures and methods described in the previous chapter. In stage 1 of the presentation, the ambient air quality prevailing in the city of Bangalore with reference to airborne Suspended Particulate Matter (SPM), Sulphur dioxide (SO_2), and Oxides of Nitrogen (NOx) during the period 1980 to 1989 is described. The importance of these three pollutants from the point of their health impact on urban communities were discussed in Chapter 2 , and here an attempt is made to observe the air quality status with particular reference to Bangalore city. In stage 2, the two-time prospective epidemiological and concurrent pollution exposure study with reference to SPM is presented to observe the health impact on the sampled population. This study was held in the selected house-holds of high pollution zones viz., the Cottonpet and the Chamarajpet divisions in the city.

4.1 STAGE 1 - AIR QUALITY STATUS

The air quality status that prevailed during the years 1980 to 1987 are considered as the main focus of the present study as this has formed the basis for commencing the Stage 2 study. This period is the retrospective period for which pollutant concentrations, as monitored at various points in the city by two different organisations, are analysed. The period between 1980 and 1984 is shown as Phase I, while the rest as Phase II (i.e., 1985

to 1989). For these phases the three pollutants viz., SPM, SO_2 and NOx are analysed conveniently to derive mainly the spatial and seasonality patterns.

Further, an evaluation and comparison of these (air quality) with reference to the permissible standards for sensitive, residential and commercial localities are carried out. These standards are the prescribed standards in India as promulgated under the provisions of "Air Act - 1981". In table 3.1 (Chapter 3) were shown the standards of SPM, SO_2 and NOx applicable to 8 and 24 hourly averaging time. It means that there exists an implied risk of "episodic nature", if the prevailing ambient air in that locality consists of continuous concentration of these pollutants, either singly or in combinations, of the levels shown in the table 3.1 during 8 or 24 hour periods. These statutory measures, in reality, are based upon the fractions of continuous concentrations of pollutants (1000 micro-g/m^3 for both SPM and SO_2 and perhaps NOx too) as observed during the historical pollution episodes in several cities. It is imperitive that the standards for sensitive zones i.e., the localities in which respiratory and cardiac patients, aged and infants are residing mainly, are strictly complied with since the risk involved is high. A certain amount of complacency however, is shown for healthy people staying in residential and commercial zones by increasing the permissible standard levels. The provisions are made with consideration to the economic criteria.

4.1.1 RETROSPECTIVE AIR QUALITY ASSESSMENT

The monitored levels of pollutants (SPM, SO_2, NOx) in various stations as obtained from Regional Occupational Health center (Indian Council for Medical Research) at Bangalore (Phase I, 1980-1984; 34 stations) and Karnataka State Pollution Control Board (Phase II, 1985-1989; 10 stations) are computed for annual mean and peak concentrations. The sampling was held as representative values of eight hourly day monitoring for SPM, SO_2, and NOx in all the stations. The same ranged widely among the stations as shown below:

Pollutant type	Mean Range	Peak Range
Phase I (1980-1984)		
SPM ($\mu g/m^3$)	36.40 - 515.26	68.60 - 1088.00
SO_2 ($\mu g/m3$)	0.62 - 26.50	1.47 - 63.69
NOx ($\mu g/^3$)	1.84 - 11.75	6.30 - 67.69
Phase II (1985-1989)		
SPM ($\mu g/m^3$)	68.20 - 386.85	62.00 - 1280.00
SO_2 ($\mu g/m^3$)	4.68 - 30.34	2.85 - 302.80
NOx ($\mu g/m^3$)	2.69 - 32.13	trace - 85.36

Further an evaluation is carried out to identify the stations where the prevailing annual concentrations of pollutants do not comply with the permissible standards. This has been presented in tables 4.1 and 4.2 for Phase I and Phase II studies respectively. Since the selection points of the monitoring stations in the city were carried out, by and large, to represent the predominant activity zones, the stations are named after Commercial (C), Industrial (I), or Residential (R) accordingly.

with reference to annual mean and peak values (SHOWN AS *)

(Note: Blanks show stations complying with the standards,
C=Commercial zone, I=Industrial zone, R= Residential zone)

PHASE I		SPM (ug/m3)						SO2 (ug/m3)						NOx (ug/m3)					
YEAR	STATIONS	ANNUAL MEAN			PEAK			ANNUAL MEAN			PEAK			ANNUAL MEAN			PEAK		
	CD	100	200	500	100	200	500	30	60	120	30	60	120	30	80	120	30	80	120
1980	C UPPARPET	*	*	*	*	*	*				*								
1980	C CORPORATION	*			*	*													
1980	C COMMERCIAL STREET				*	*													
1980	C KSRTC	*	*		*	*	*												
1980	C K.R.MARKET	*	*		*	*													
1980	I PEENYA				*														
1980	I RAJAJINAGAR				*														
1980	I BYAPPANAHALLI				*														
1980	I HEBBAL	*			*	*					*								
1980	I JALAHALLI				*														
1980	I MYSORE ROAD	*			*	*					*	*							
1980	R ULSOOR				*														
1980	R BANASHANKARI																		
1980	R MALLESHWARAM																		
1980	R JAYANAGAR				*														
1981	C SRIRAMPURAM(CWO)	*			*	*													
1981	C KALASIPALYA(CWO)	*			*	*													
1981	C BVKIYENGARROAD(CMH)	*			*	*													
1981	C QUADRANTCIRCLE(AH)	*			*	*													
1981	C KVTEMPLEST(CHO)	*	*		*	*	*									*			
1981	C GANDHINAGAR(CGHS)	*	*		*	*	*												
1981	I MAGADIROAD	*			*														
1981	I GAVIPURAM(CMH)				*														
1981	I GORIPALYA(CMH)				*														
1981	I AZADNAGAR(MH)				*														
1981	R INDIRANAGAR(ANH)	*			*	*	*												
1981	R QUEEN'SROAD(CNERO)	*			*	*													
1981	R RAJAJINAGAR(CWO)	*			*														
1981	R CNOR	*			*	*													
1981	R RAJAJINAGAR(MH)				*														
1981	R NEELASANDRA(CD)	*			*	*													
1981	R CHAMRAJPET(CDO)	*	*		*	*	*												
1981	R GFROAD(CWO)	*			*														
1981	R CMH				*														
1981	R MALLESHWARAM(CWO)	*			*	*													
1982	C KVTEMPLE(MH)	*			*	*	*												
1982	I GAVIPURAM	*			*	*											*		
1982	I BAPUJINAGAR	*	*		*	*											*		
1982	I GORIPALYA	*			*	*					*						*	*	
1982	I AZADNAGAR	*			*	*													
1982	R NORTHRANGEOFFICE	*			*	*													
1982	R ULSOOR				*	*											*		
1983	I GORIPALYA(MH)				*														
1983	R DASAPPANURSINGHOME	*			*	*											*		
1983	R ULSOOR(MH)				*														
1984	C KVTEMPLE(MH)	*	*		*	*													
1984	R DASAPPANURSINGHOME	*			*	*											*		
1984	R ULSOOR(MH)				*												*		

TABLE 4.2 Monitoring stations not complying with "Standards" of SPM, SO2 AND NOx with reference to annual mean and peak values (SHOWN AS *)

(Note: Blanks show stations complying with the standards, C=Commercial zone, I=Industrial zone,& R= Residential zone)

PHASE II		SPM (ug/m3)						SO2 (ug/m3)						NOx (ug/m3)					
YEAR	STATIONS	ANNUAL MEAN			PEAK			ANNUAL MEAN			PEAK			ANNUAL MEAN			PEAK		
	CD	100	200	500	100	200	500	30	60	120	30	60	120	30	80	120	30	80	120
1985	C ANANDARAO CIRCLE	*	*		*	*	*												
1985	C KRMARKET	*	*		*	*													
1985	I PEENYA	*			*														
1985	I HOSUR ROAD	*			*	*													
1985	I G I B U	*			*	*													
1985	I K.S.& D.L	*			*	*					*								
1985	I AMCO	*			*														
1985	R JAYANAGAR				*	*													
1985	R BOWRING	*			*														
1985	R MALLESHWARAM	*			*	*													
1986	C ANANDARAO CIRCLE	*	*		*	*	*				*								
1986	C KRMARKET	*	*		*	*													
1986	I G I B U	*			*														
1986	I AMCO	*			*	*		*											
1986	I K.S.& D.L	*			*	*					*								
1986	I HOSUR ROAD				*														
1986	I PEENYA	*			*	*													
1986	R BOWRING	*			*														
1986	R MALLESHWARAM				*														
1986	R JAYANAGAR				*														
1987	C KRMARKET	*			*	*													
1987	C ANANDARAO CIRCLE	*	*		*	*	*												
1987	I AMCO	*			*	*													
1987	I K.S.& D.L	*			*	*													
1987	I HOSUR ROAD				*														
1987	I G I B U	*			*	*													
1987	I PEENYA	*			*	*					*								
1987	R BOWRING				*														
1987	R MALLESHWARAM	*			*														
1987	R JAYANAGAR				*														
1988	C KRMARKET	*			*	*	*				*	*							
1988	C ANANDARAO CIRCLE	*	*		*	*	*				*	*	*			*	*		
1988	I K.S.& D.L	*	*		*	*	*				*	*				*			
1988	I G I B U	*	*		*	*	*				*	*				*			
1988	I HOSUR ROAD	*			*	*					*	*							
1988	I PEENYA	*	*		*	*	*				*	*				*			
1988	I AMCO	*	*		*	*	*	*			*	*	*			*	*	*	
1988	R JAYANAGAR	*			*	*					*	*							
1988	R MALLESHWARAM	*			*	*					*	*	*			*			
1988	R BOWRING				*	*					*	*							
1989	C ANANDARAO CIRCLE	*	*		*	*	*	*			*	*		*		*	*		
1989	C KRMARKET	*			*	*													
1989	C COTTONPET	*	*		*	*	*												
1989	I G I B U	*	*		*	*	*				*	*	*			*			
1989	I AMCO	*	*		*	*	*	*			*	*				*			
1989	I HOSUR ROAD	*	*		*	*	*												
1989	I PEENYA	*	*	*	*	*	*				*								
1989	R CHAMARAJPET	*			*	*										*			
1989	R JAYANAGAR	*			*	*					*	*							
1989	R BOWRING				*						*								
1989	R MALLESHWARAM				*	*					*								

(STANDARDS EXPRESSED AS MICRO-G/CUBIC METERS; AVERAGING EIGHT HOURLY)

PHASE II

YEAR	CD	STATIONS	SPM STANDARD 100	200	500	SO2 STANDARD 30	80	120	NOx STANDARD 30	80	120
1985	C	ANANDARAO CIRCLE	93	80	22	1			2	1	
1985	C	K.R.MARKET	85	39	3						
1985	I	AMCO BATTERIES	68	26	2	21	3		4		
1985	I	K.S.& D.L	36	16	2						
1985	I	G.I.B.U.	41	9	2	4	2				
1985	I	PEENYA	48	16							
1985	I	HOSUR RD (YENKY)	48	17	4						
1985	R	MALLESHWARAM	67	17							
1985	R	BOWRING HOSPITAL	50	21	4	4					
1985	R	JAYANAGAR	19	4							
1986	C	ANANDARAO CIRCLE	90	79	26	1			1		
1986	C	K.R.MARKET	93	62	2						
1986	I	AMCO BATTERIES	89	40		37	6				
1986	I	K.S.& D.L	43	12		8					
1986	I	G.I.B.U.	59	31	4	12					
1986	I	PEENYA	59	35	3						
1986	I	HOSUR RD (YENKY)	22	11					71	29	18
1986	R	MALLESHWARAM	26			3					
1986	R	BOWRING HOSPITAL	51	9					2		
1986	R	JAYANAGAR	20	7							
1987	C	ANANDARAO CIRCLE	95	83	21						
1987	C	K.R.MARKET	76	41	3						
1987	I	AMCO BATTERIES	84	26							
1987	I	K.S.& D.L	52	22							
1987	I	G.I.B.U.	57	9		8	3				
1987	I	PEENYA	82	43	2						
1987	I	HOSUR RD (YENKY)	26	2							
1987	R	MALLESHWARAM	47	16							
1987	R	BOWRING HOSPITAL	39	19	3						
1987	R	JAYANAGAR	27	2							
1988	C	ANANDARAO CIRCLE	94	83	27	39	2		6		
1988	C	K.R.MARKET	57	26	2	36	0				
1988	I	AMCO BATTERIES	96	57	1	27	5	3	12	1	1
1988	I	K.S.& D.L	77	44	2	26			1		
1988	I	G.I.B.U.	56	26	15	36	2		1		
1988	I	PEENYA	81	46	6	20			1		
1988	I	HOSUR RD (YENKY)	37	11		24					
1988	R	MALLESHWARAM	51	21		19	1	1	5		
1988	R	BOWRING HOSPITAL	22	6		31	1				
1988	R	JAYANAGAR	66	13		13					
1989	C	ANANDARAO CIRCLE	56	46	4	28	1		30	2	
1989	C	K.R.MARKET	55	26	2	7	1		6		
1989	C	COTTONPET	100	97	34	6	6	3	3		
1989	I	AMCO BATTERIES	80	40	3	38	8	3	8		
1989	I	K.S.& D.L	50	15	3	22	4	2	6		
1989	I	G.I.B.U.	36	7		5			2		
1989	I	PEENYA	25	25	25						
1989	R	CHAMARAJAPET	93	36		6					
1989	R	MALLESHWARAM	18	9							
1989	R	BOWRING HOSPITAL	70	40	10						
1989	R	JAYANAGAR	27								

However, a certain mixing of all three activities invariably prevails within any zone. Thus, it implies that a pure zone of either of these does not really exit. For example, a central commercial station such as the one located at K R Market, is infact, situated near the dental college premises which includes a large hospital (Victoria and Vanivilas general and maternity hospitals) area and this can become a sensitive locality too. Secondly, many of the monitoring stations from among the Phase I analysis are situated in the premises of maternity homes and hospitals. These have been indicated in brackets in table 4.1 after naming the stations.

In general, the location points of commercial stations represent the central part of the corporation area of the city, whereas the industrial stations are at the periphery. The residential stations are the representatives of intervening area between central and peripheral region.

Considering the above mentioned mixture of activities and the categories of residing population in these zones, evaluations are carried out for the standards (sensitive, residential and industrial) as depicted in tables 4.1 and 4.2. It is apparent that a majority of the stations do not comply (shown as * in tables 4.1 and 4.2) with the standard levels set for sensitive people especially in case of annual mean and peak levels in SPM. Next to this, the industrial and residential stations follow in order of the risk involved.

With respect to SO_2 and NOx, the non-compliance is sparse during the retrospective period (1980-1987). But in 1988 and 1989 (prospective periods) there is an alarming trend in case of SO_2 as can be seen from the above mentioned tables. Further analysis, which is shown below confirms these observations.

Here computations are carried out by per ten station basis "non-compliance" in each year of the study. This enables a comparison between the years. The number of stations counted as not complying from table 4.1 and 4.2 with the three sets of permissible standards for SPM, SO_2, NOx are shown below in Tables 4.3, 4.4 and 4.5 respectively.

4.3 SPM (µg/m3)

YEAR	Total stations	Annual Mean 100	200	500	Annual peak 100	200	500
1980	15	4	2	1	9	5	1
1981	20	8	2		10	6	2
1982	7	10	1		10	10	1
1983	3	3			10	3	
1984	3	7	3		10	7	
1985	10	9	2		10	7	1
1986	10	7	2		10	5	1
1987	10	7	1		10	6	1
1988	10	9	5		10	10	6
1989	11	8	5	1	10	9	5

Note that the noncompliance with respect to 200 is 5/10 in annual mean levels during 1988 and 1989. The total picture indicates that the level of pollution due to SPM are on the rise as for as the residential exposures are considered.
The same can be substantiated through the peak exposure analysis from above table 4.3.

4.4 SO_2 ($\mu g/m^3$)

YEAR	Total stations	Annual Mean 30	60	120	Annual peak 30	60	120
1980	15				2	1	
1981	20						
1982	7				1		
1983	3						
1984	3						
1985	10				1		
1986	10	1			2		
1987	10				1		
1988	10	1			10	10	3
1989	11	2			6	4	1

It can be seen that the non-compliance is evident in 1988 and 1989 which perhaps is a gradual deteriorating trend in air quality with respect to SO_2.

4.5 NOx ($\mu g/m3$)

YEAR	Total stations	Annual Mean 30	80	120	Annual peak 30	80	120
1980	15						
1981	20				1		
1982	7				6	1	
1983	3				3		
1984	3				7		
1985	10						
1986	10						
1987	10						
1988	10				6	2	1
1989	10	1			4	1	

This pattern suggests a lower degree of deterioration in air quality with respect to NOx as can be attributed to only peak concentrations exceeding the standards. Only one station in 1989 has shown non-compliance with respect to annual mean NOx.

It was mentioned in Chapter 2, that the pollution

monitoring schedules in Phase I and Phase II studies were different because of their objectives. In Phase I, the number of days of monitoring (9 to 42 days) among the stations were fewer although there were more stations. In phase II, the monitoring was carried out on a weekly basis covering almost 52 days in a year, though there were only ten stations. In fact, in one station (Anandarao Circle), monitoring was done almost on every alternate days. Considering these advantages the percentage of days during which the stations showed non-compliance were computed for the years 1985 to 1989 (phase II). This has been presented in table 4.3.

It can be observed in this table that the percentage of days not complying with the standards is more in the case of sensitive standards compared to residential one. That with respect to residential are comparitively more than in industrial. The average percentages confining to these are presented according to the following zones :

ZONE	SPM STANDARD			SO_2 STANDARD			NOx STANDARD		
	100	200	500	30	80	120	30	80	120
COMMERCIAL	81	60	13	13	1		4		
INDUSTRIAL	56	25	3	14	2		4	1	1
RESIDENTIAL	43	14	1	6					

It can be readily observed that from the above the air quality non-compliance for SPM is more predominant in commercial zone followed by industrial and residential zones. In case of SO_2 and NOx the levels of non-compliance are minimal. This observation

suggests that identifying the pollution zones for health studies should follow the SPM factor first as its intensity with respect to non-compliance of standards are evident. Secondly, SO_2 and NOx can be considered as subsequent factors. Considering these observations further analysis to derive the spatial and the seasonal distribution of the pollutants have been carried out as described in sections 4.1.2 and 4.1.3.

4.1.2 SPATIAL DISTRIBUTION PATTERN OF POLLUTANTS

The isoline representation of Airborne Particulate Matter concentration (SPM) is shown in figures 4.1 to 4.6. Figure 4.1 represents the period between 1980 to 1984 (Phase I) while figures 4.2 to 4.6 represent 1985 to 1989 period (Phase II). Since the levels shown by these isolines represent yearly mean concentrations, they can be compared readily with a standard of 200 $\mu g/m^3$ refered as the permissible limit prescribed for a residential locality. The regions confined to these (200 $\mu g/m^3$) isolines were selected as high pollution zones for a prospective epidemiological survey in the present study.

It can be observed through figures 4.1 to 4.6 that approximately 21 km2 area located at the central region and a part of the adjacent south-west region has experienced high pollution level almost continuously. The actual variation throughout the entire year and between the years are shown in section 4.1.3. In order to indicate the density of population in the region a map of various divisions indicating high densities of population were super-imposed on the figures showing the

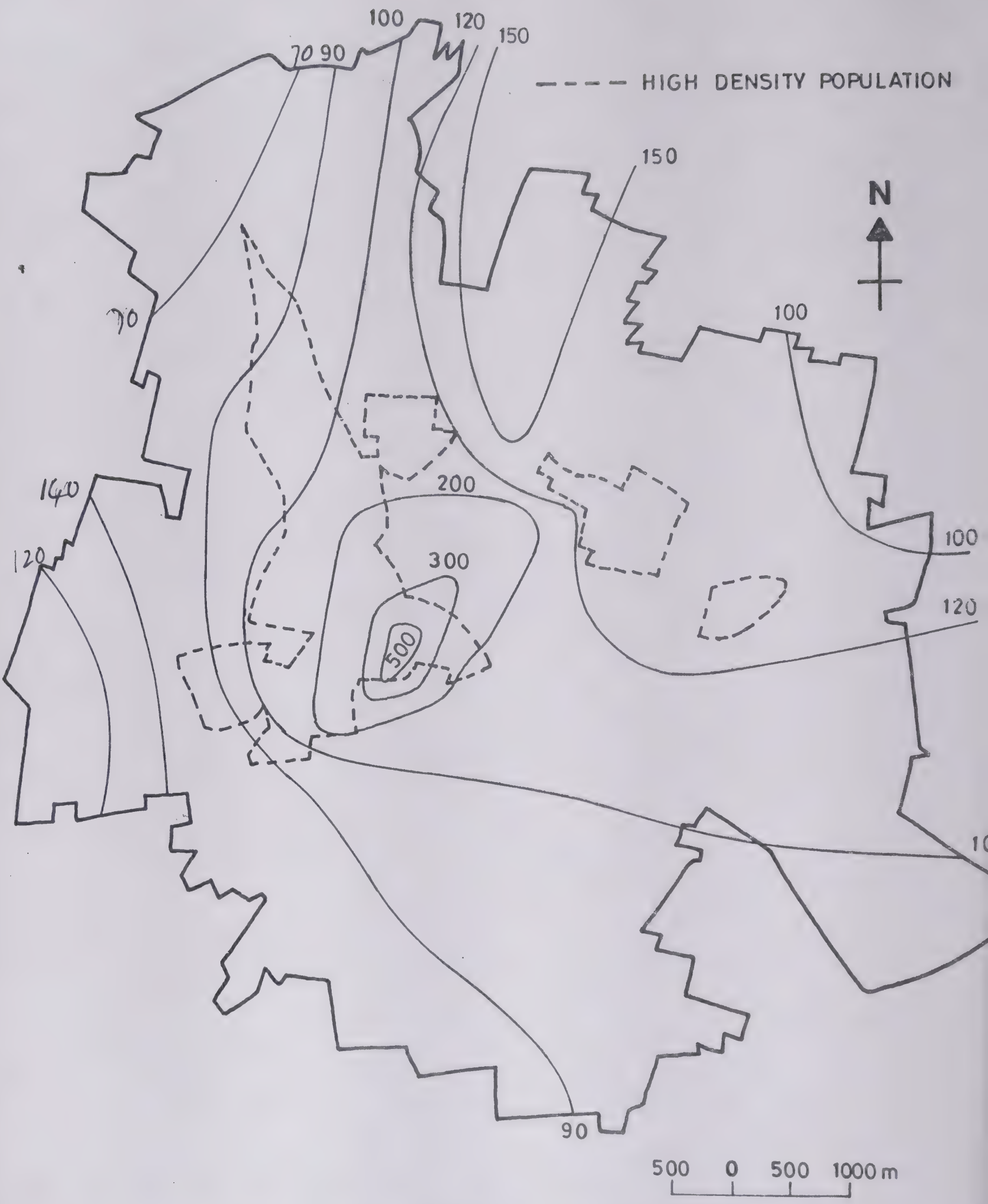

FIG. 4.1 ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF SUSPENDED PARTICULATE MATTER (SPM) IN BANGALORE. (YEAR : 1980-1984)

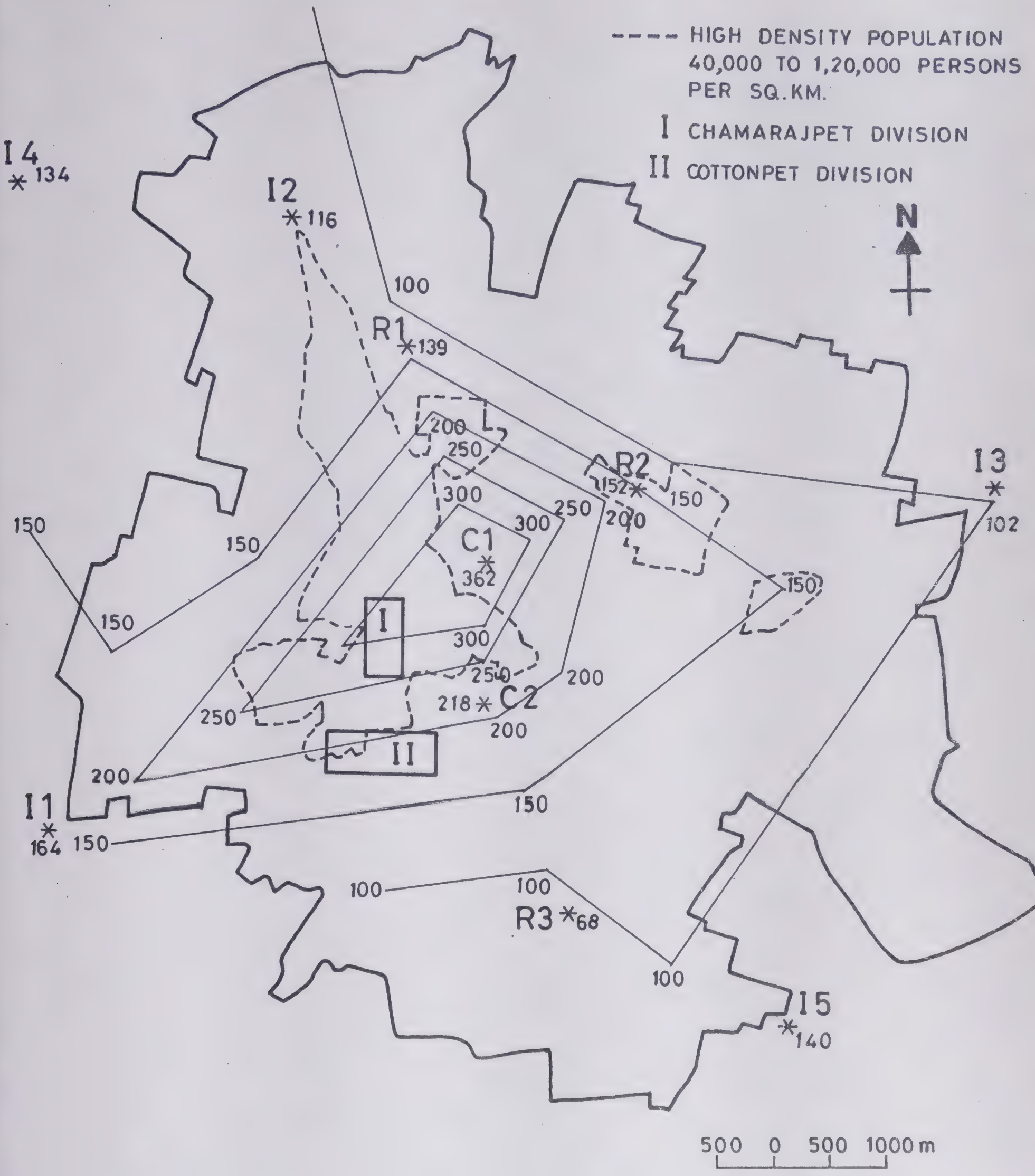

FIG. 4.2a ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF SUSPENDED PARTICULATE MATTER (SPM) IN BANGALORE. (YEAR : 1985)

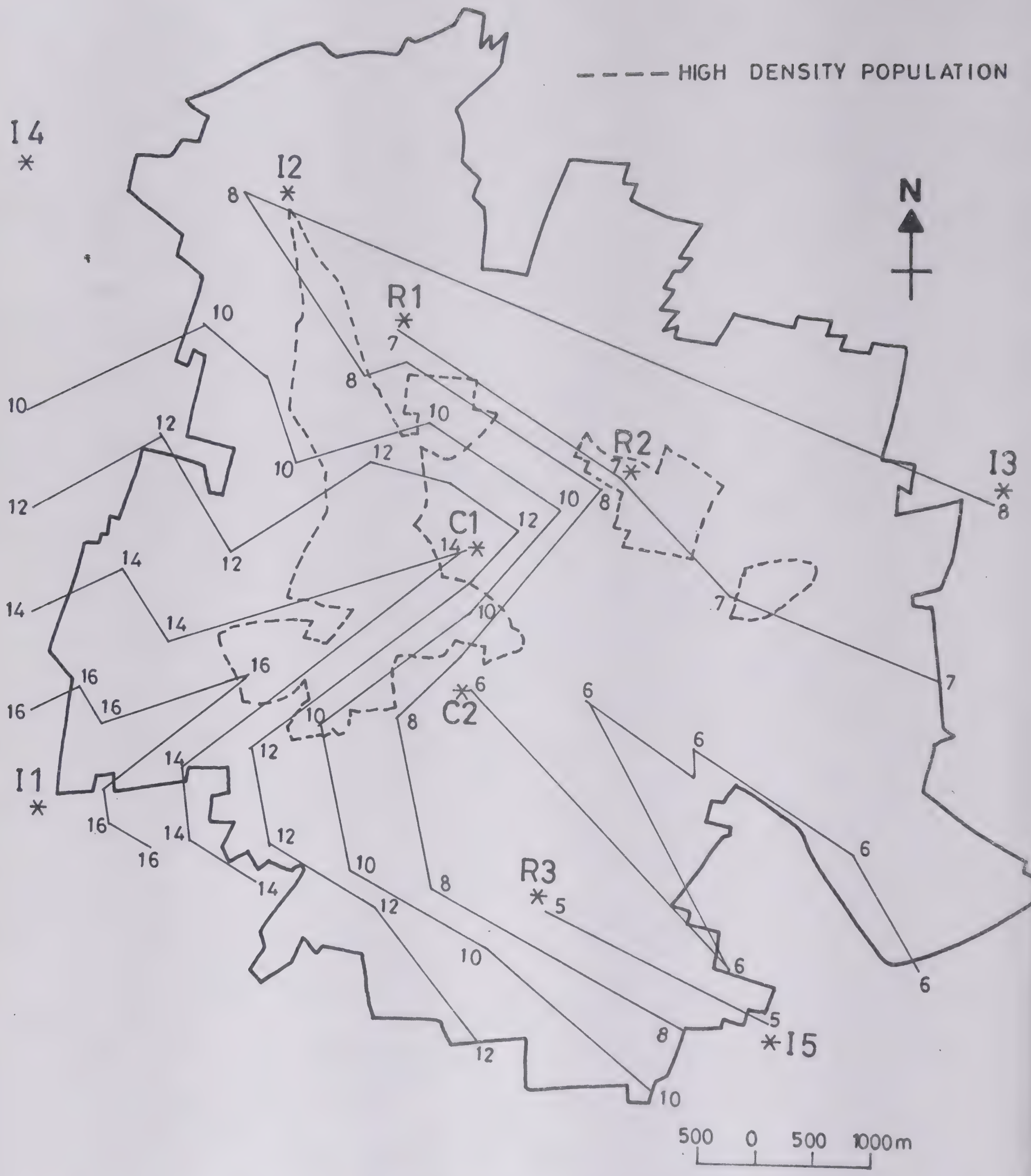

FIG. 4.2b ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF SULPHUR DIOXIDE (SO_2) IN BANGALORE (YEAR : 1985)

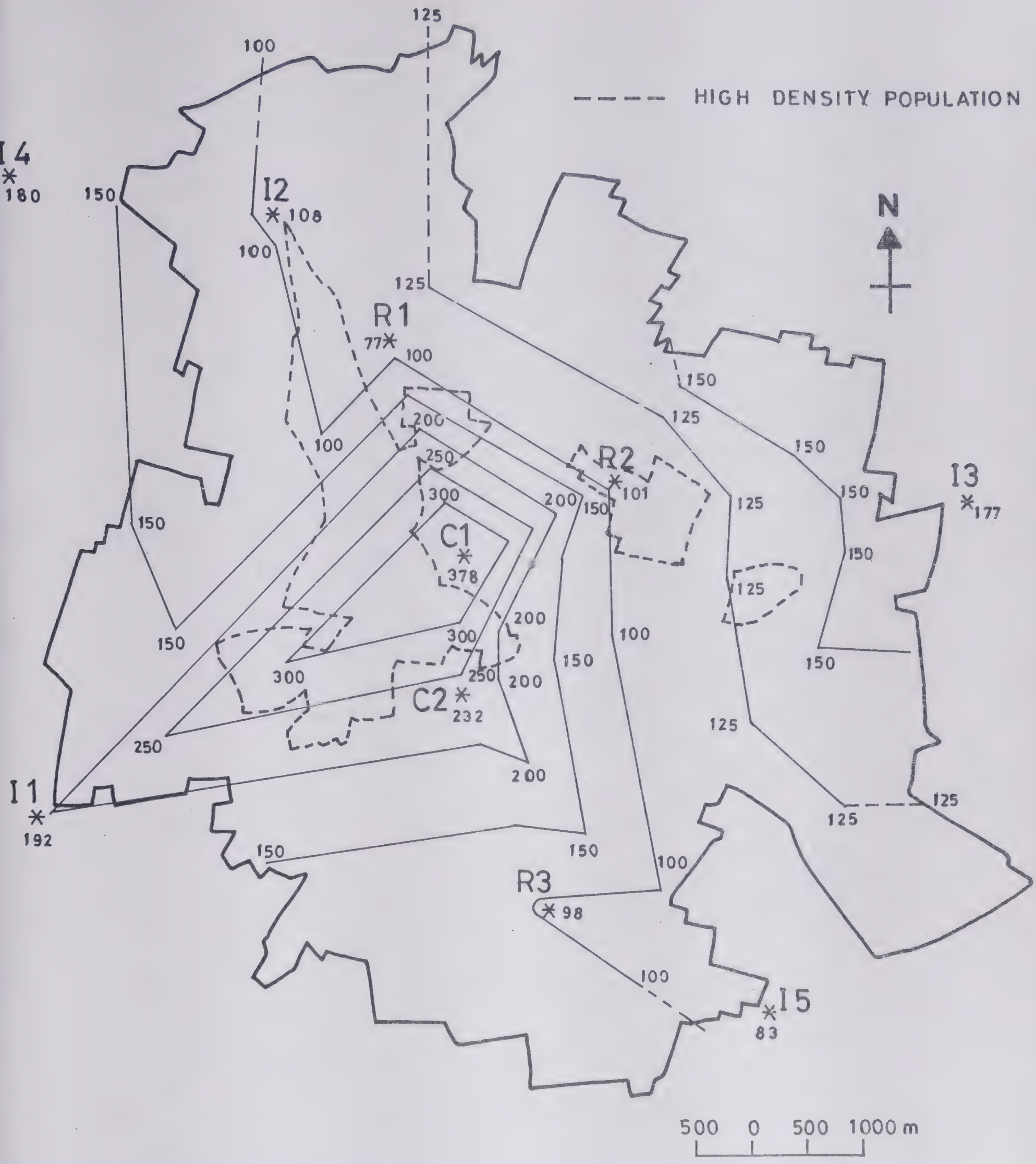

FIG. 4.3 ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF SUSPENDED PARTICULATE MATTER (SPM) IN BANGALORE. (YEAR : 1986)

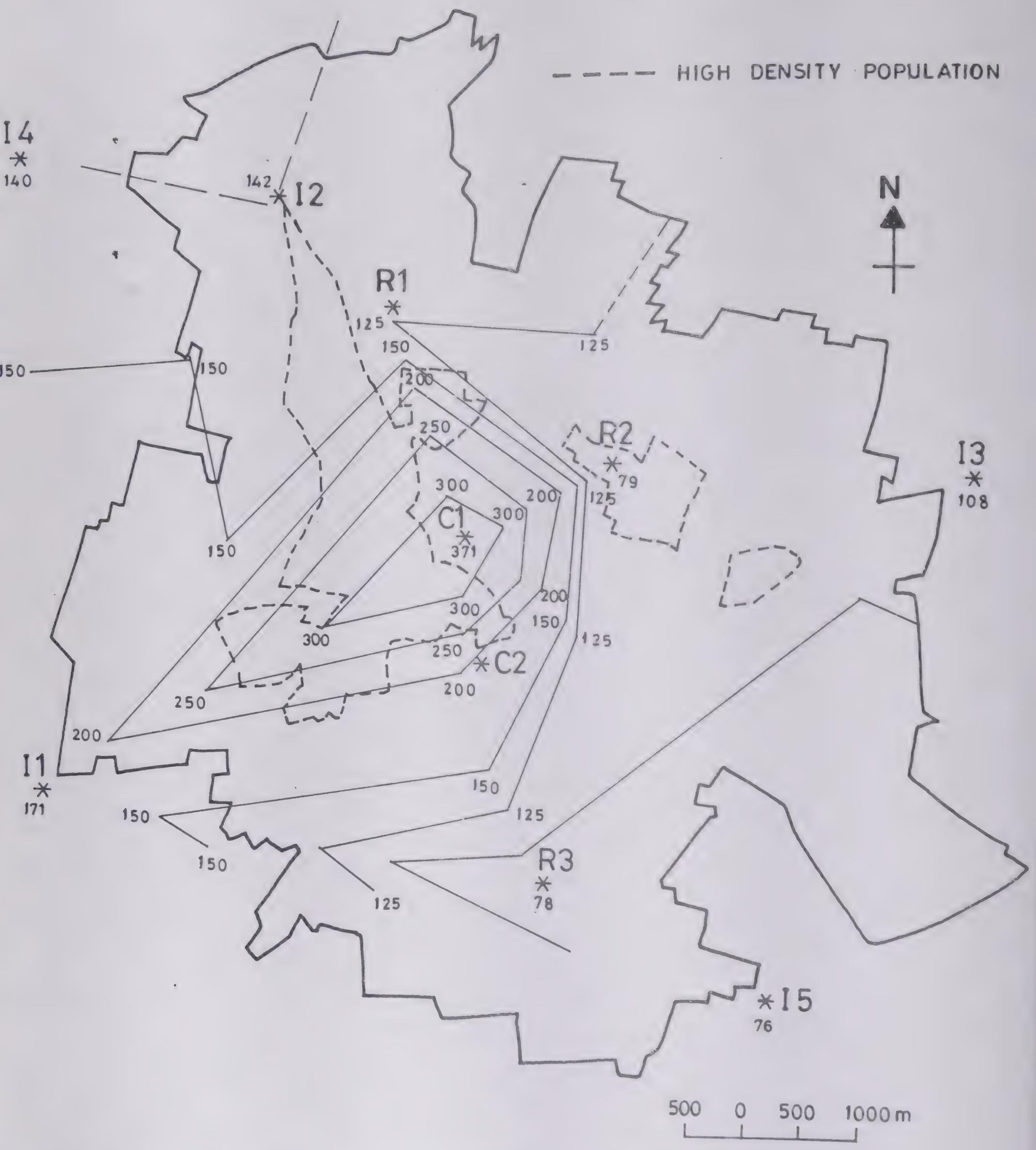

FIG. 4.4a ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF SUSPENDED PARTICULATE MATTER (SPM) IN BANGALORE. (YEAR : 1987)

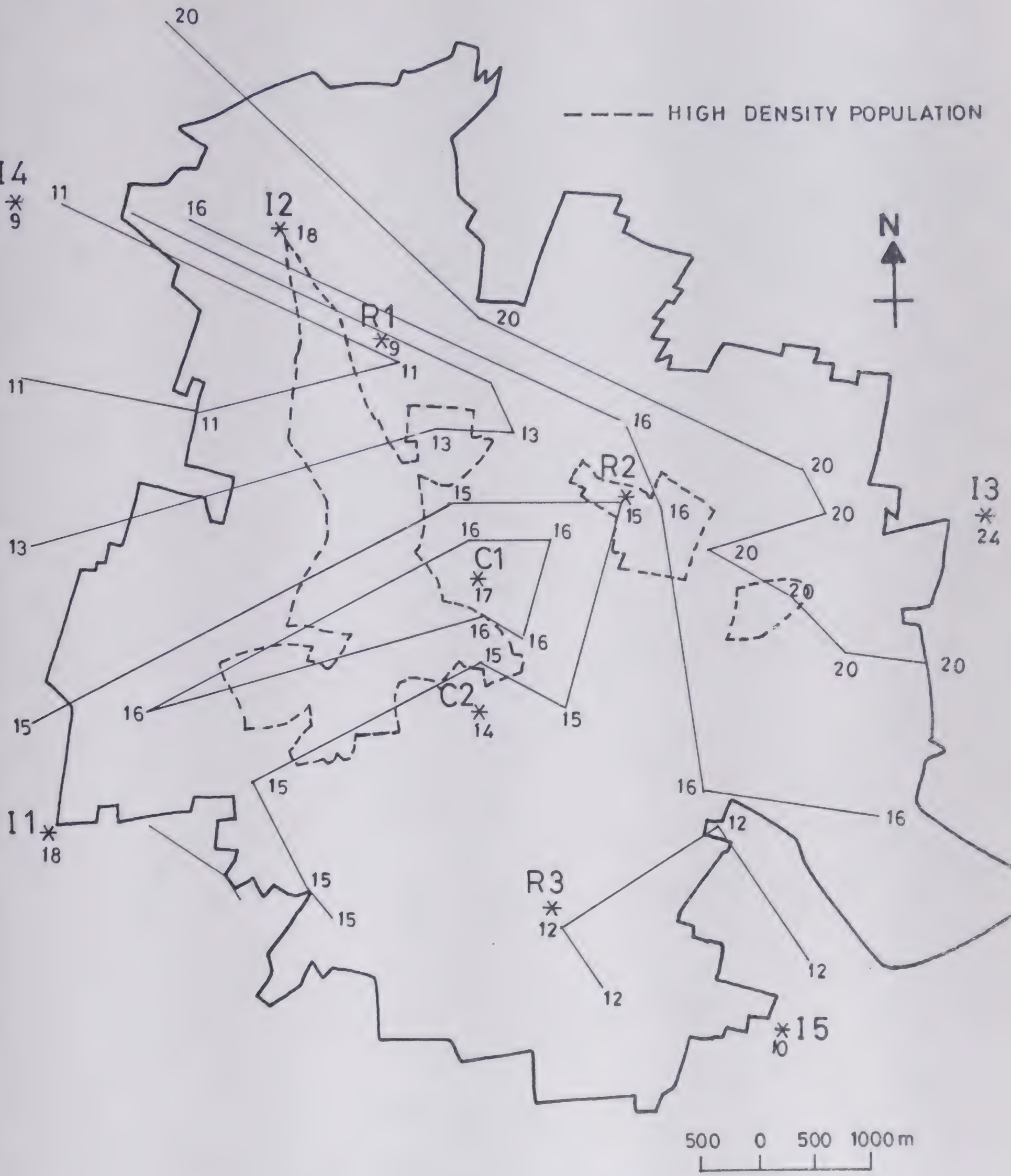

FIG. 4.4b ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF SULPHUR DIOXIDE (SO_2) IN BANGALORE. (YEAR : 1987)

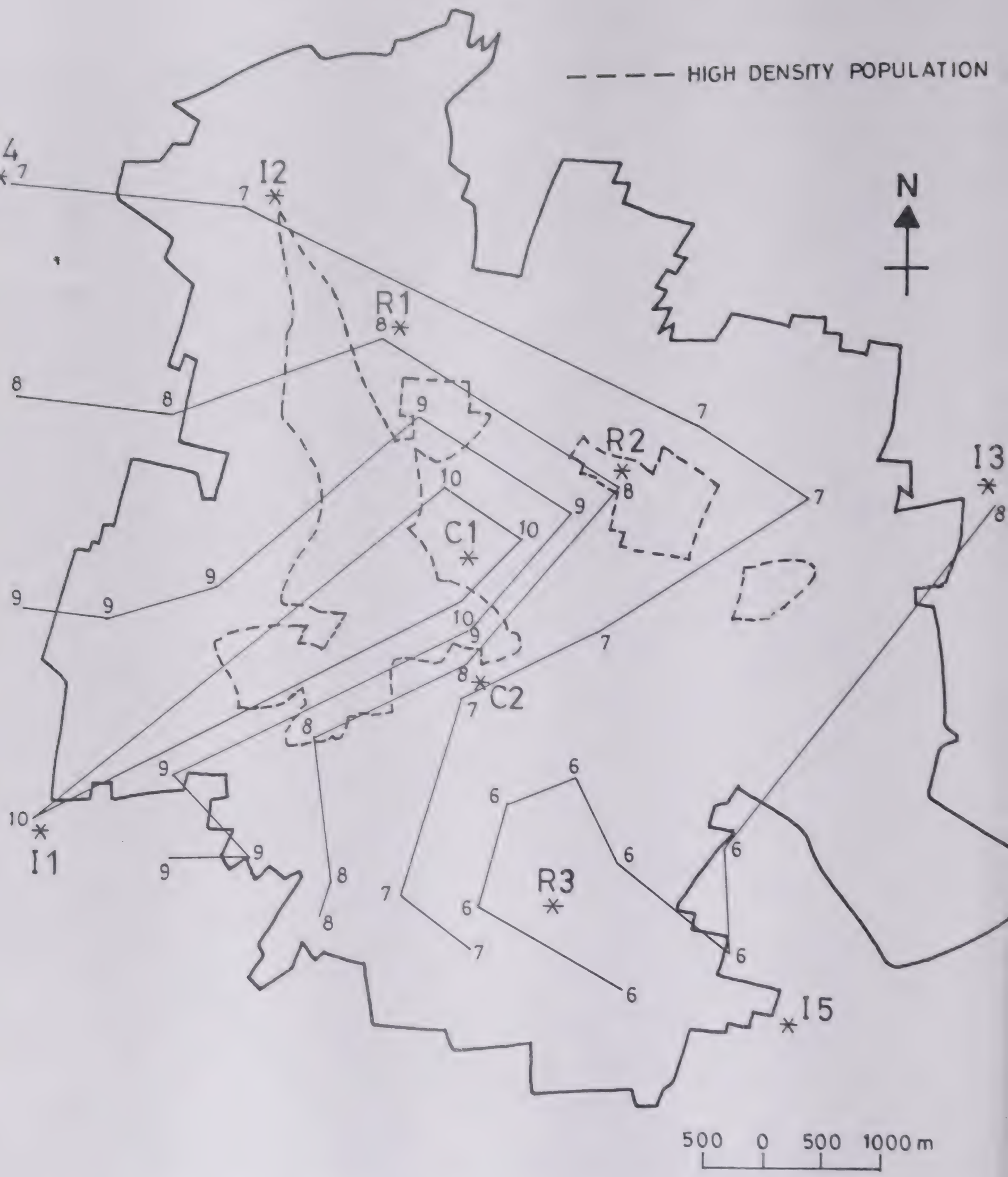

FIG. 4.4c ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF OXIDES OF NITROGEN (NO_x) IN BANGALORE. (YEAR : 1987)

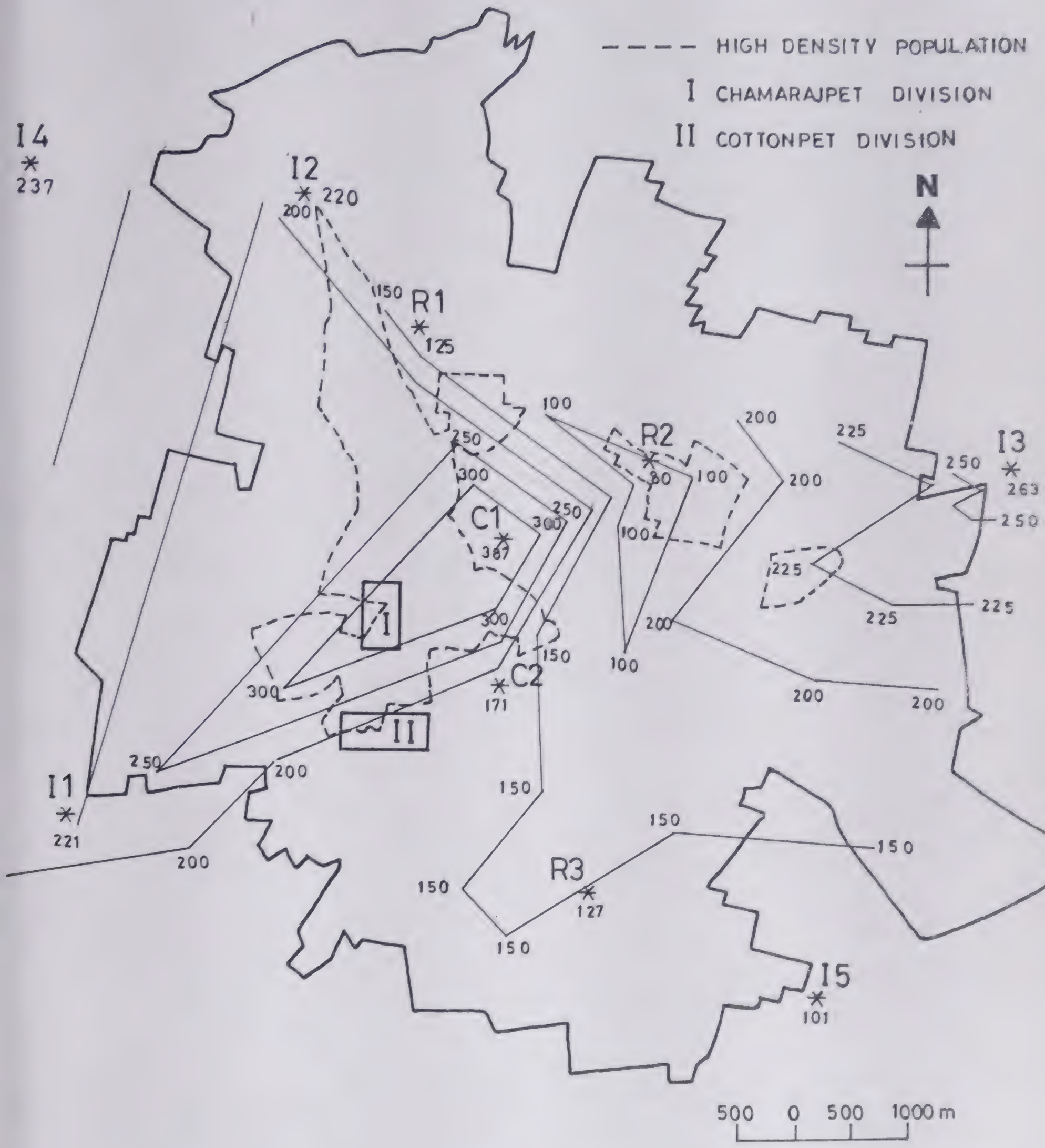

FIG. 4.5 ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF SUSPENDED PARTICULATE MATTER (SPM) IN BANGALORE. (YEAR : 1988)

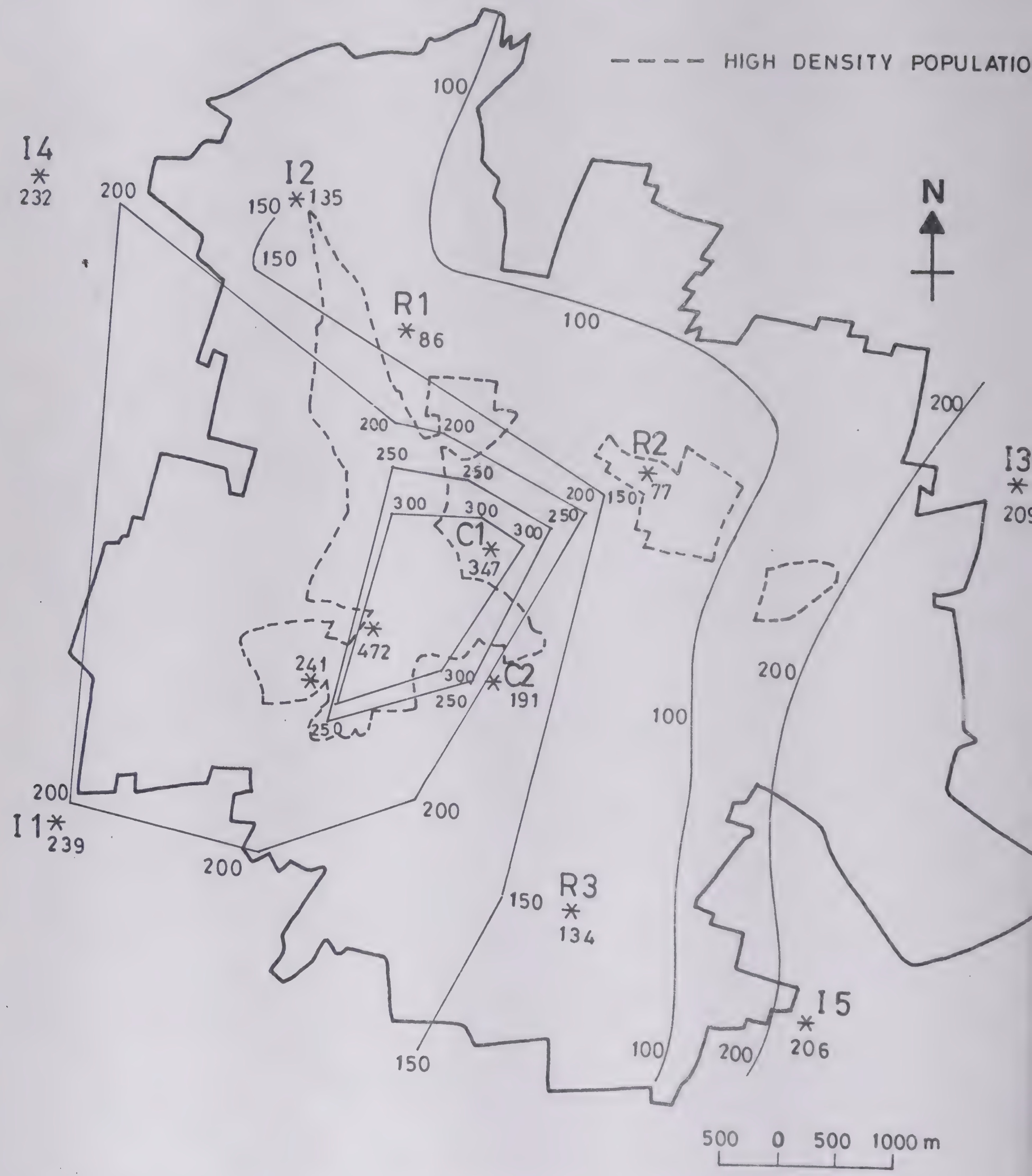

FIG. 4.6a ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF SUSPENDED PARTICULATE MATTER (SPM) IN BANGALORE. (YEAR : 1989)

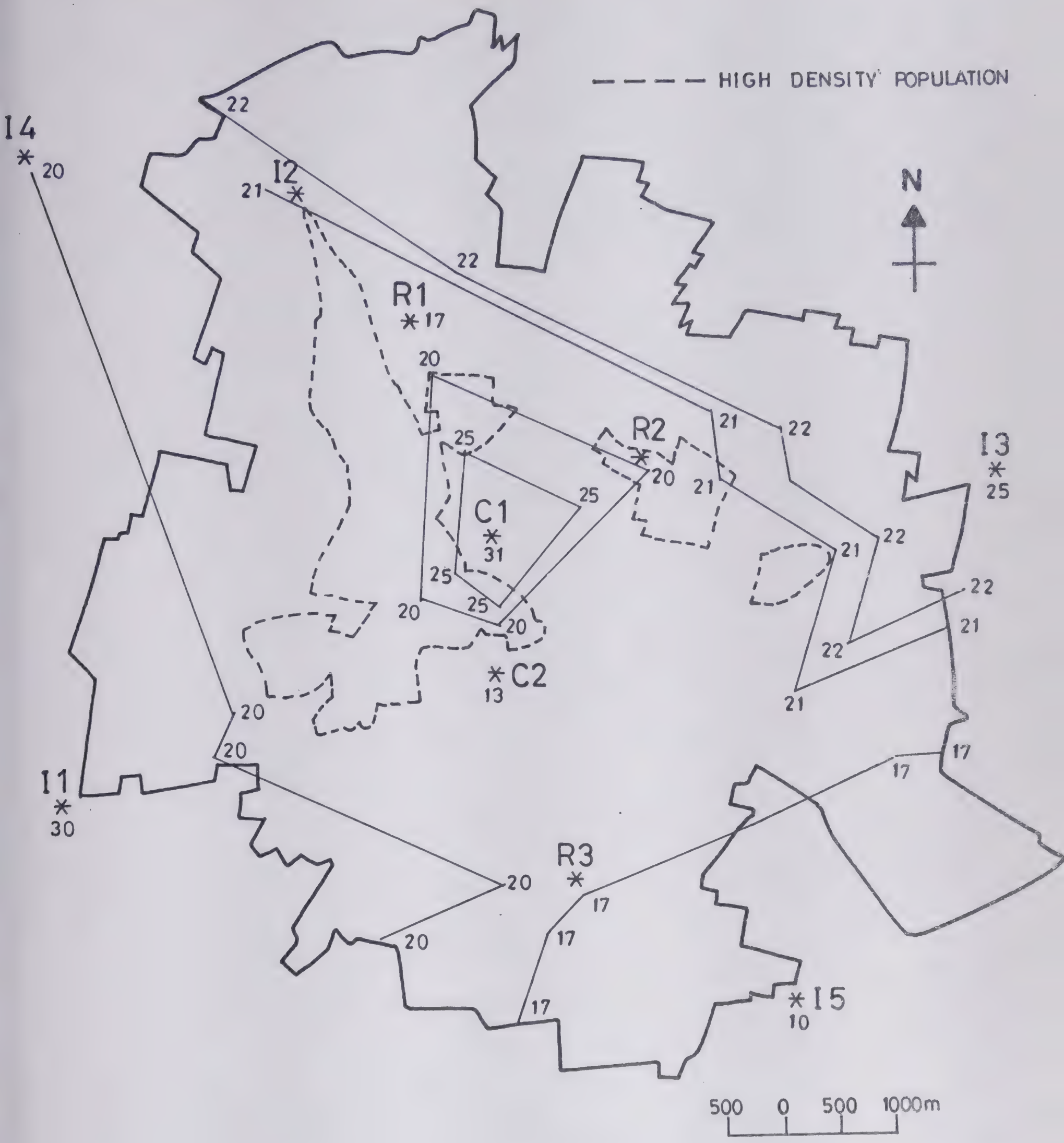

FIG. 4.6b ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF SULPHUR DIOXIDE (SO_2) IN BANGALORE. (YEAR : 1989)

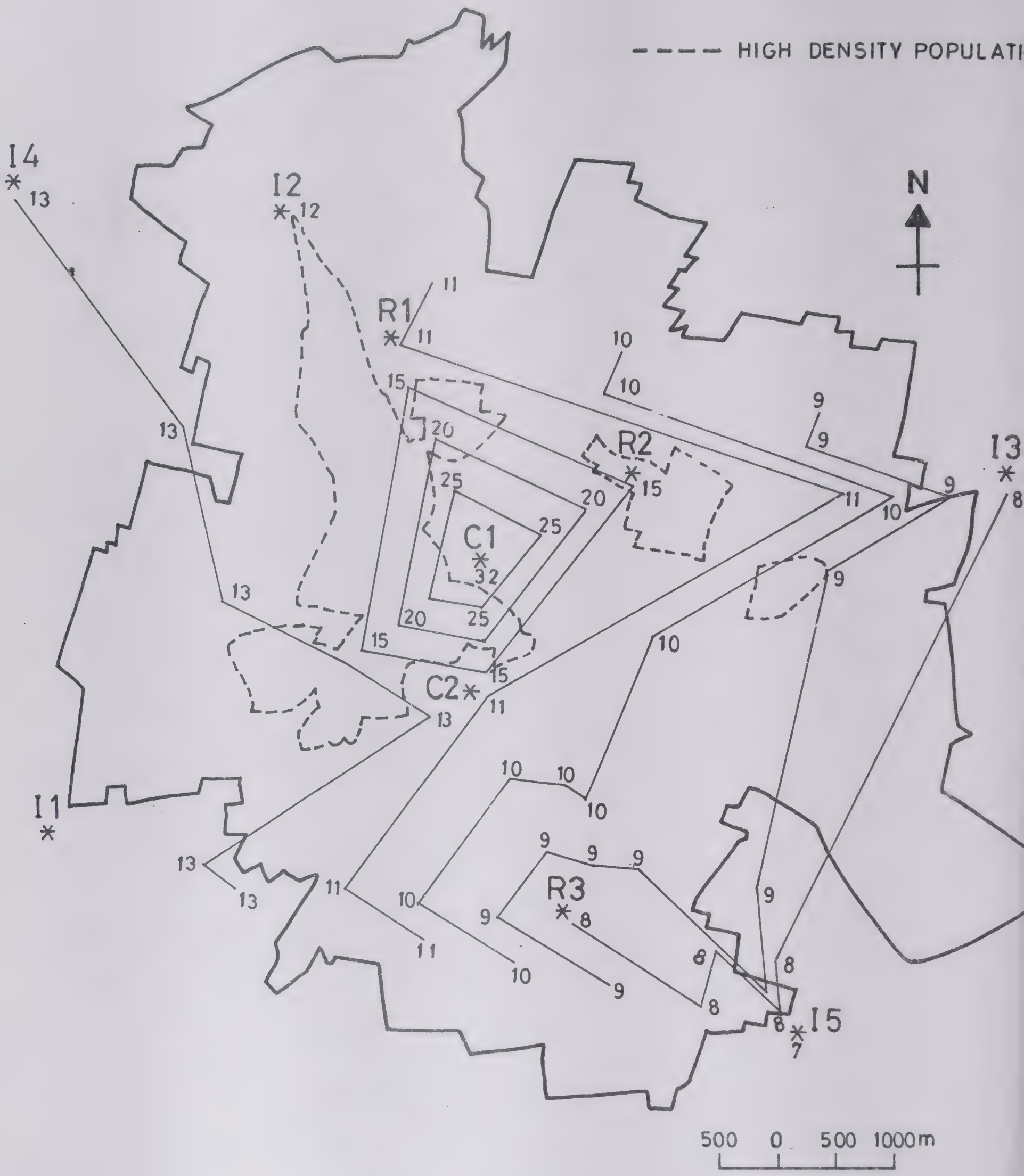

FIG. 4.6c ISOLINES DEPICTING ANNUAL MEAN CONCENTRATIONS OF OXIDES OF NITROGEN (NO_x) IN BANGALORE. (YEAR : 1989)

pollution isolines. These densities were derived from 1981 Census in India.

It can also be stated at this point that the high level of SPM concentration can be attributed to the topographic features, population density, commercial activity as well as high automotive congestion in this region. The housing inequalities and unplanned layouts of commercial and residential buildings have resulted in a density of 40,000 to 1,20,000 people per square km area. Due to increasing commercial activity in the region the heavy traffic vehicles operate both during day and night time especially in the region extending towards south-westerly direction i.e., the Mysore Road area. In addition to these, the congestion in traffic due to vehicles ranging from two-wheelers, cars, goods vehicles to public transport buses is increasing year by year (Rao, 1987). It is stated that the vehicles invariably pass through this region since this is the least distant and major transporation linkage between the peripheral industrial and residential areas in the city. The average vehicular speed is around 7 and 10 km per hour according to an estimate in 1986.

From the analysis of spatial distribution of pollutants, it is evident that the area of the city can be divided in to three zones. A centrally located high pollution zone of approximately 21 km^2 and the outer moderately polluted zone of 119 km^2 engulfing the entire corporation limits. However, the outermost semi-concentric area consists of the industrial and

farming zone of nearly 200 km^2 show relatively less pollution. But the general trends of pollution levels within and between the years are in the upward direction especially in case of SPM in all the three areas as can be seen in the follwing sections.

4.1.3 SEASONAL VARIATIONS OF POLLUTANTS

As mentioned in section 3.1.2 (Chapter 3), the seasonal variations are shown from Phase II retrospective study mainly because of continuity in the data with respect to monthly concentrations. Considering the spatial distribution of SPM in main and SO_2 with NOx as subsidiaries according to the degree of their prevelances, the monitoring stations are combined seperately as representatives of two zones. The first zone is a high pollution zone with (1) Anandarao Circle, (2) K R Market and (3) AMCO batteries as shown in earlier tables (tables 4.2 and 4.3). Similarly, the second zone is a moderate pollution zone with seven other stations shown in the above mentioned tables. These are used for pooling the data.

The mean monthly data from high and moderate pollution zones (pooled data) corresponding to the years 1985, 1986, 1987, 1988, and 1989 are shown in figures 4.7a, 4.8a, and 4.9a for SPM, SO_2, and NOx respectively. These figures depict the seasonal variation in the pollutants with respect to these two zones. Also shown in these figures are the general trends. The trends are computed using deseasonalised data and regressing it upon 60 months (1985-1989). A standard computer package (STATPACK, "DESEASON" NWA Computer Utilities) is used to

obtain deseasonalised data and the seasonal indexes. Further the annual mean concentrations of pollutants are multiplied by the seasonal indexes to obtain seasonal cycles.The same have been presented in figures 4.7b, 4.8b, and 4.9b respectively for the three pollutants for each zone.

In the present analysis, the seasonal variations in pollutants can be attributed to (i) the general trend, plus (ii) the seasonal cycles mainly and (iii) the rest is due to unexplained variations.

The general trends shown in figures 4.7a, 4.8a and 4.9a are obtained by simple linear regressions as explained earlier. The R (correlation) values for SPM, SO_2, NOx for each of the two pollution zones are 0.17, 0.44 ; 0.74, 0.86 ; and 0.67, 0.73 correspondingly. The indications are that the trends with respect to SPM are not very marked, but for SO_2, and NOx are significantly more marked. An increasing pollution trend by years can be readily observed from these figures except in case of SPM (Fig.4.7a). Perhaps the trend of SPM appears to be increasing slightly between 1985 and 1988, and there is a sudden drop. This can be attributed to the change in the height of monitoring equipment at one station (Anandarao Circle). Until 1988, the height was with in 10 ft above the ground, but in 1989 and from the month of june it is elevated to a height of 30 ft for certain reasons. The seasonality charecterestics of SPM, SO_2, and NOx are further discussed seperately below.

Seasonality Characterestics of Airborne Particulate Matter (SPM)

With reference to seasonality characterestics in SPM during 1985 to 1988, except perhaps in monsoon period, the fluctuations are not very significant in both high and moderate pollution zones as can be seen from figure 4.7b. But the levels of SPM between the zones is quite contrasting. In high pollution zone, it varied between 310 and 380 µg/m3 and the drop during monsoon period especially in the month of September is 200 $\mu g/m^3$. In moderate pollution zone, it varied between 98 and 140 µg/m3 with a peak being found in the month of June.

It can be explained that the pollutants encountered in high pollution zone are mostly arising out of combustion of petroleum based fuels (smoke density) which are likely to be brought down by rain water. Such emissions are caused by heavy vehicular congestion in this area. In case of the peak shown in moderate pollution zone during the month of June, it can be stated that this upsurge could be due to the presence of biogenic material such as pollen and spores. It is likely that the common weeds such as parthenium variety and fungal groups become quite active immediately after the first monsoon period in Bangalore.

Seasonality Characterestics of Ambient Sulphur dioxide, (SO_2)

The seasonality variation of ambient SO2 as depicted in figure 4.8b does not seem to follow the same pattern as observed in the case of SPM. The pattern of variation in both the zones is that a gradual increase of 10 $\mu g/m^3$ to 32 $\mu g/m^3$ in the months of

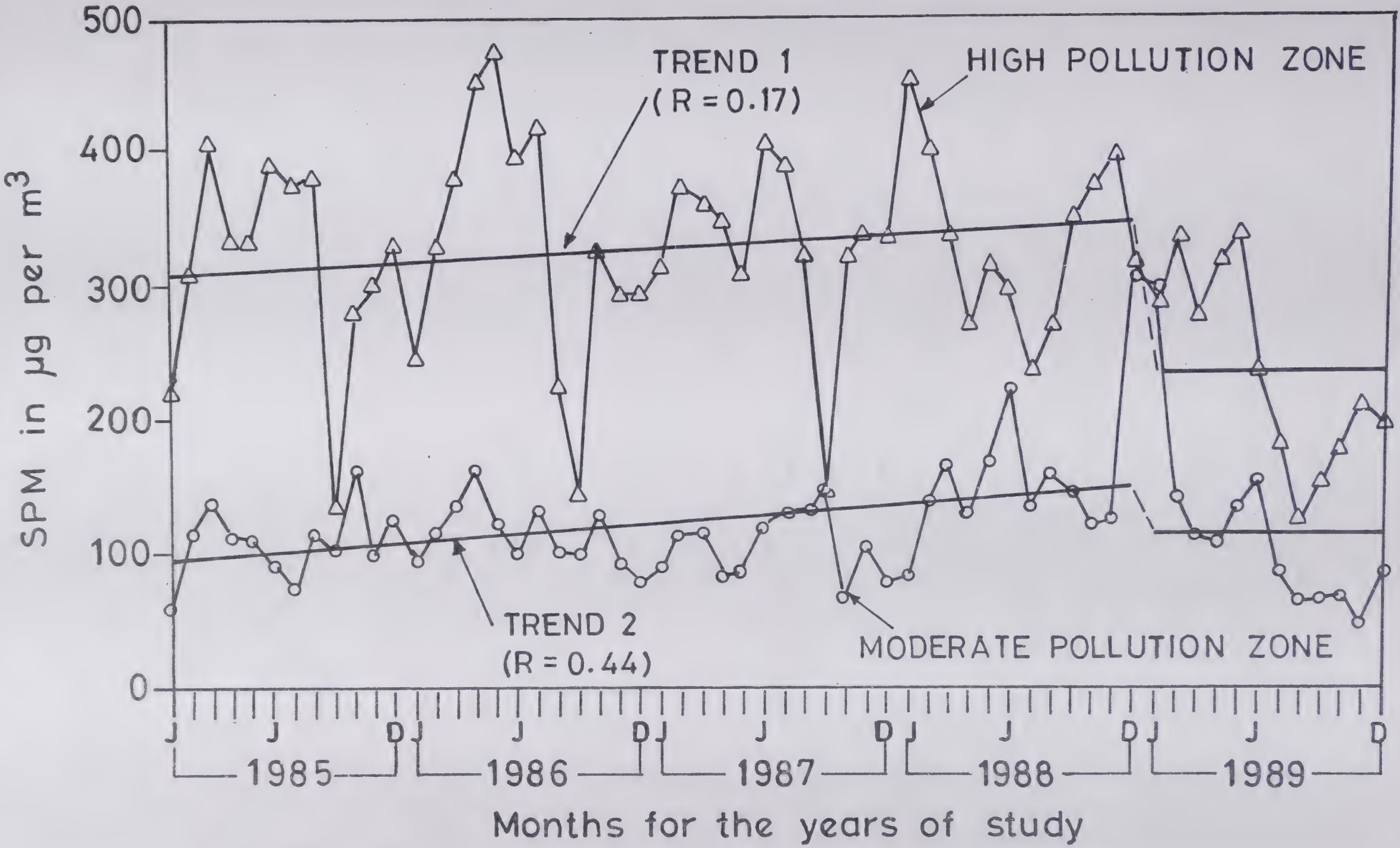

FIG.4.7a SEASONALITY AND TRENDS IN SPM AT HIGH AND MODERATE POLLUTION ZONES.

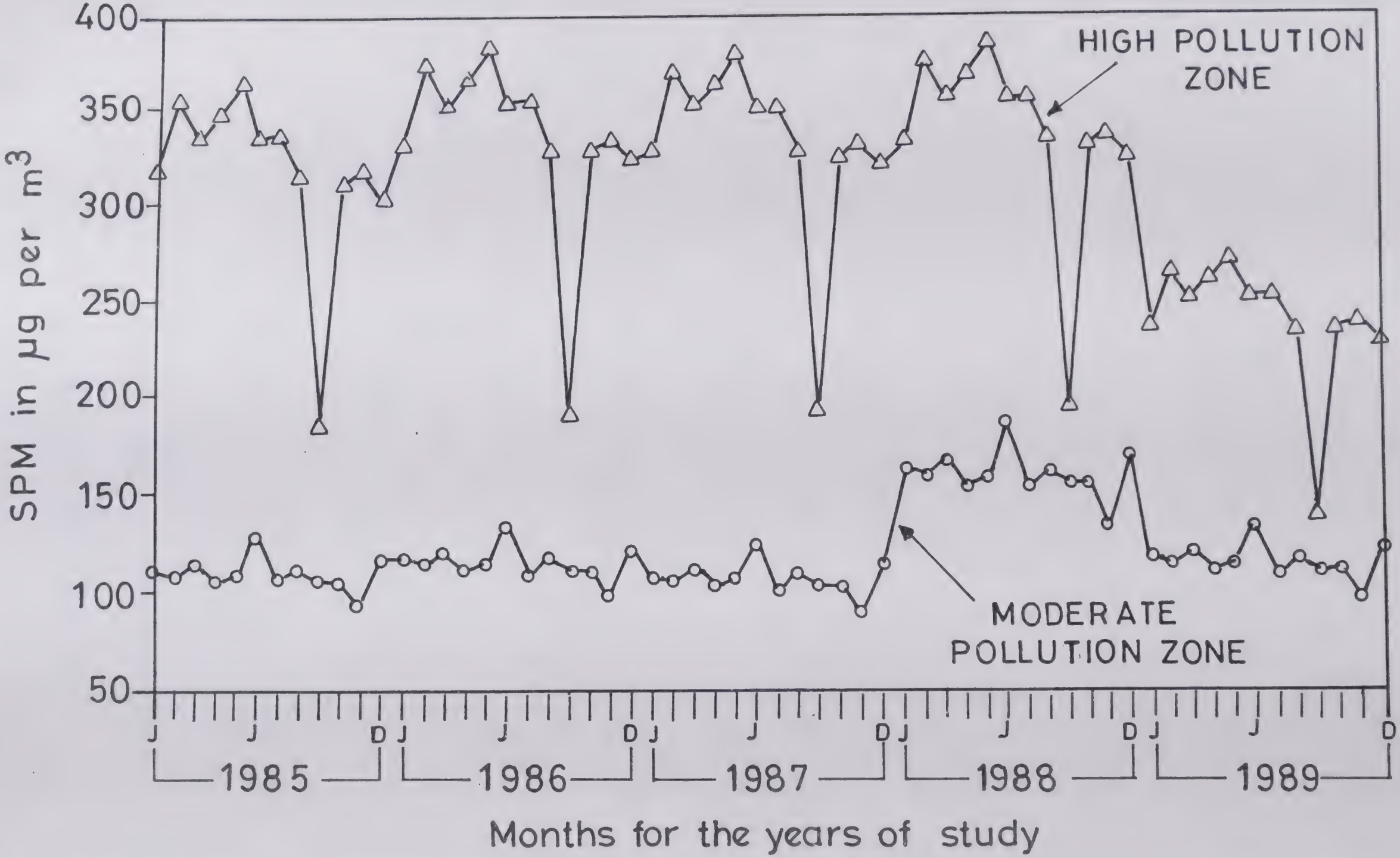

FIG. 4.7 b SEASONALITY CYCLES IN SPM AT HIGH AND MODERATE POLLUTION ZONES.

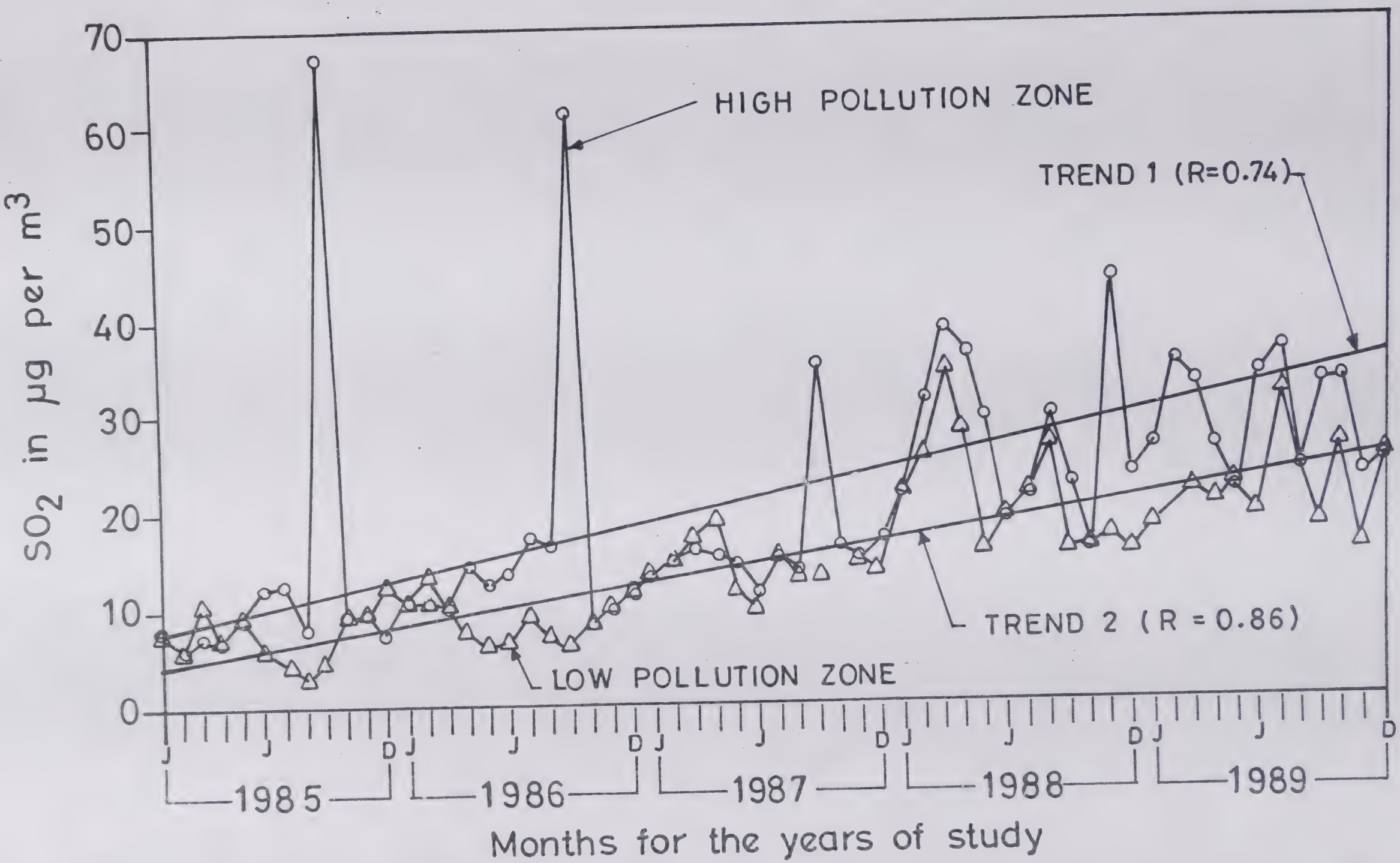

FIG. 4.8a SEASONALITY AND TRENDS IN SO_2 AT HIGH AND MODERATE POLLUTION ZONES.

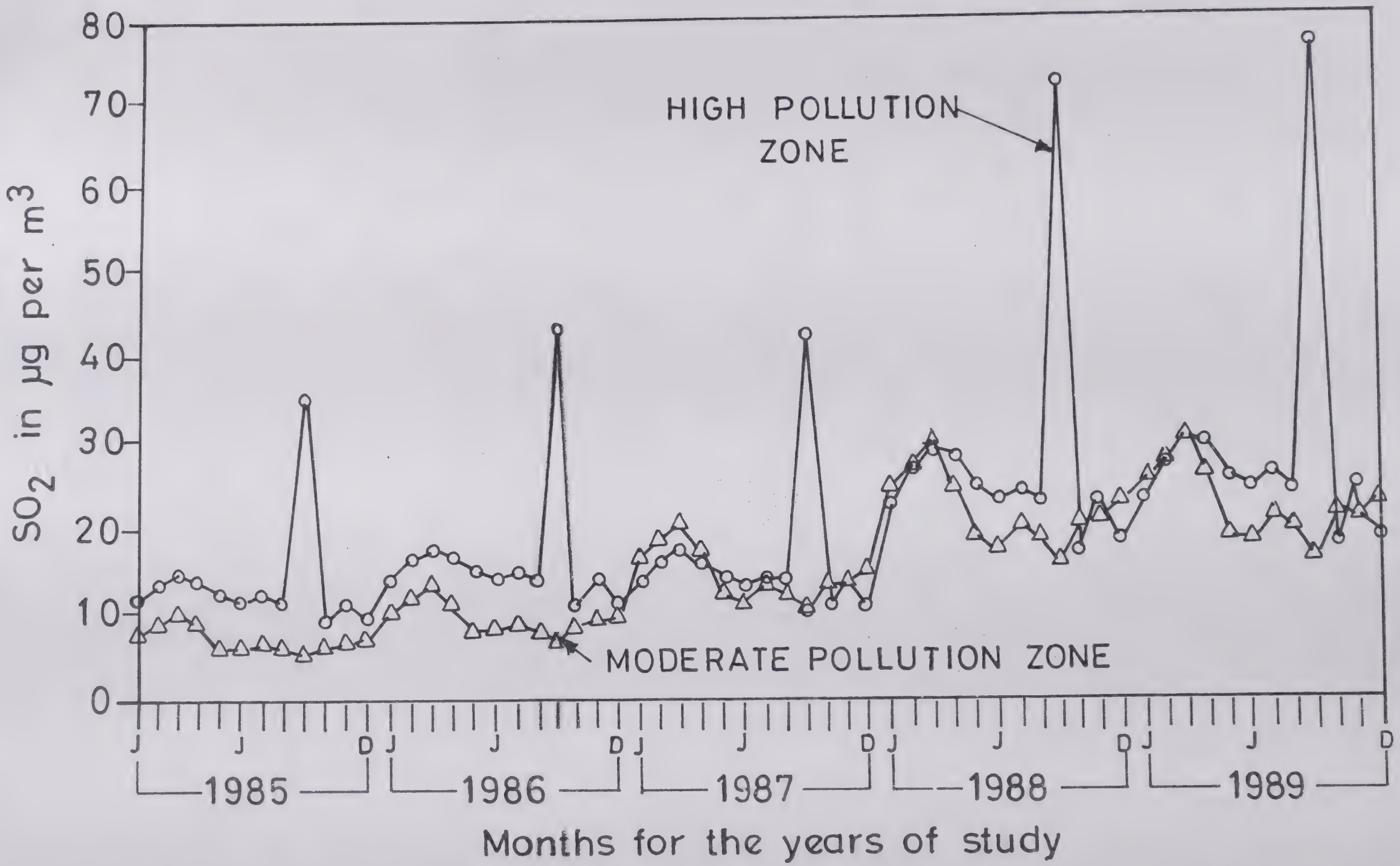

FIG. 4.8b SEASONALITY CYCLES IN SO_2 AT HIGH AND MODERATE POLLUTION ZONES.

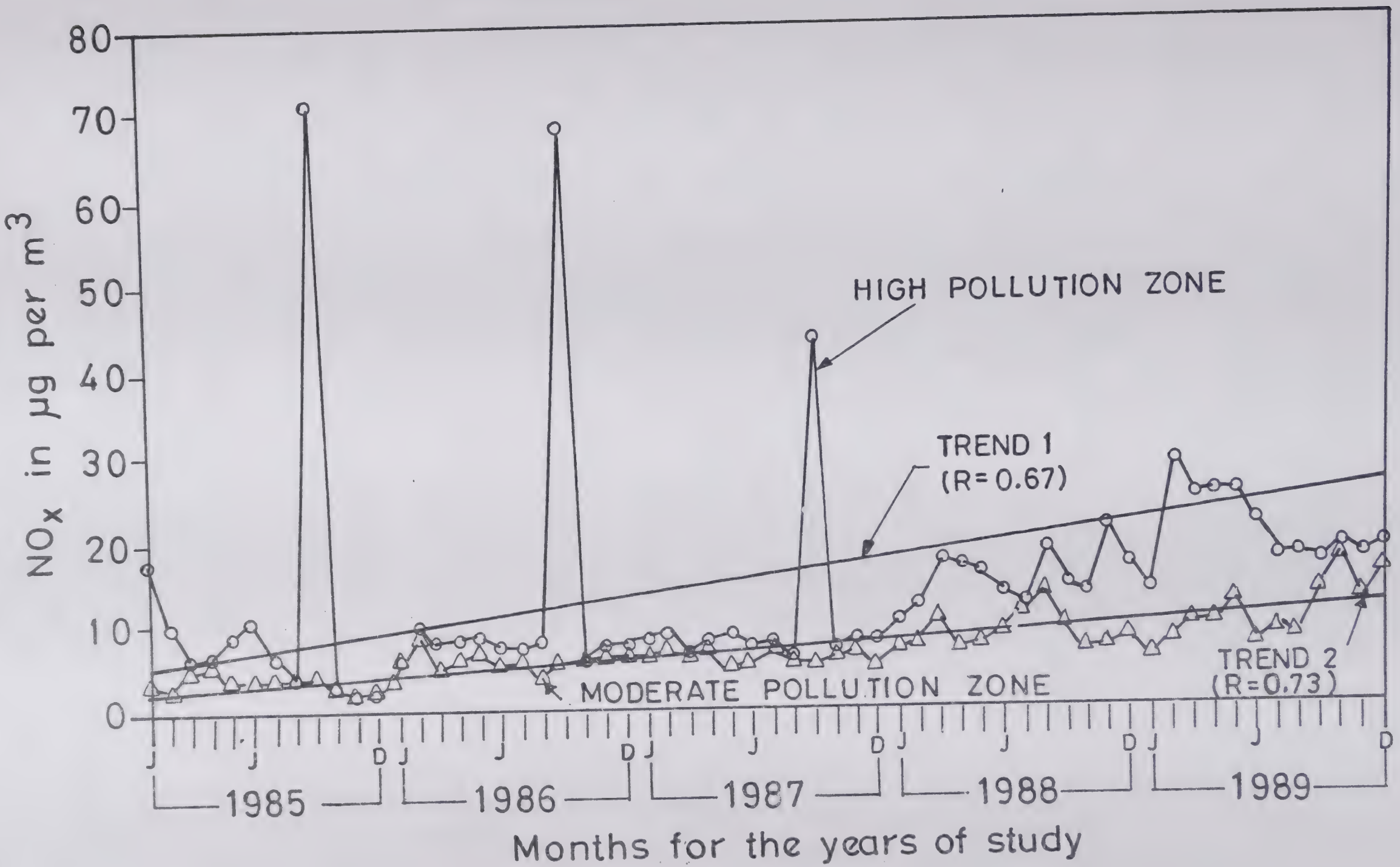

FIG.4.9a SEASONALITY AND TRENDS IN NO_x AT HIGH AND MODERATE POLLUTION ZONES.

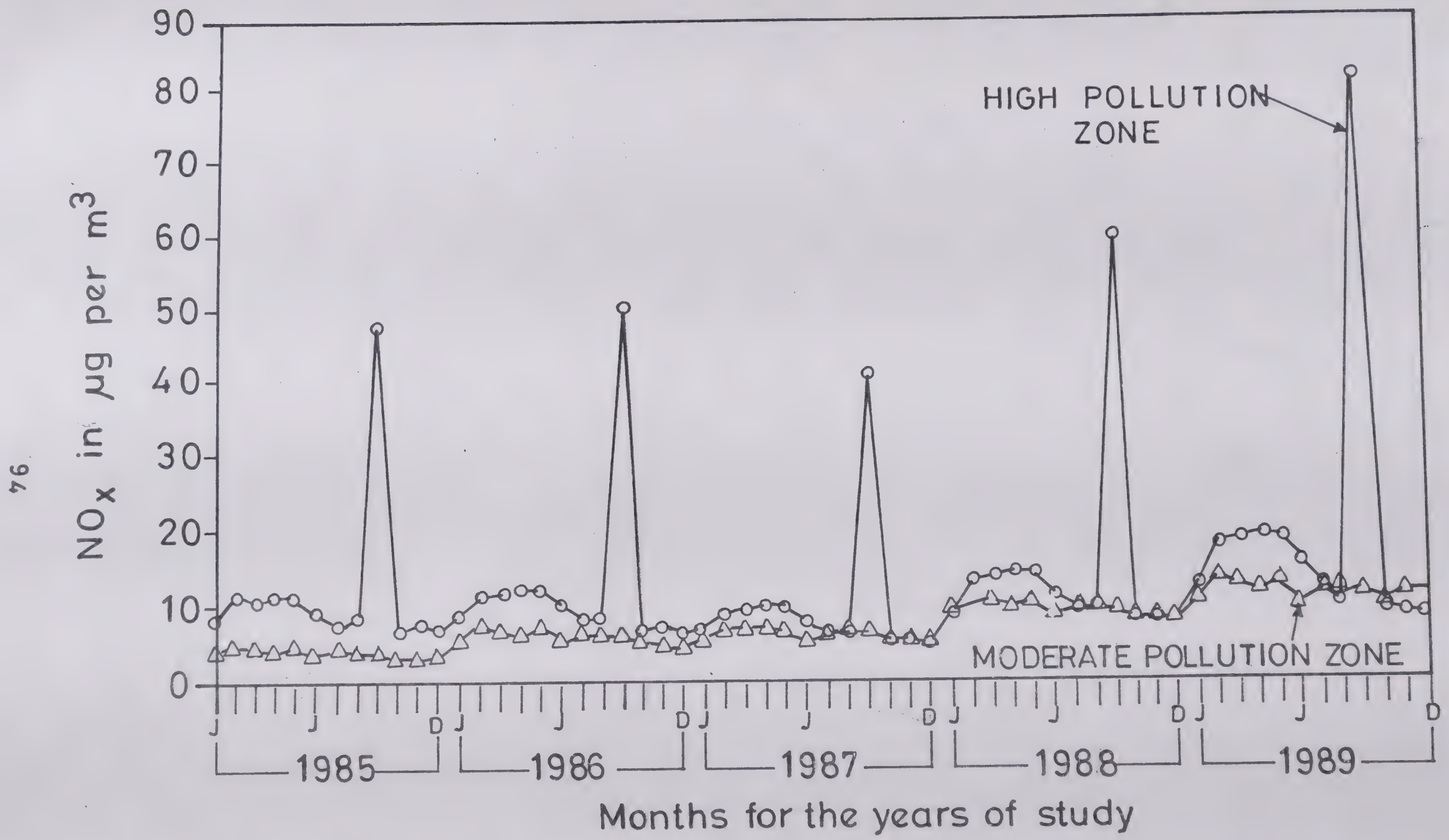

FIG. 4.9b SEASONALITY CYCLES IN NO_x AT HIGH AND MODERATE POLLUTION ZONES.

February and March. Again thereafter a slight decrease till August. But there is a sudden increase of 38 $\mu g/m^3$ to 78 $\mu g/m^3$ in the month of September especially in the high pollution zone. This phenomenal increase could be due to excessive humidity in the region. This could result in the formation of acidity in the atmosphere.

The ambient SO2 trend in both high and moderate pollution zones is observed to be increasing steadily over the years although the levels do not exceed the minimum permissible standard of 30 $\mu g/m3$ until 1987. However, it has exceeded this limit in 1989. From the point of residential exposures, it can be stated that these levels would exceed the permissible standard of 80 $\mu g/m^3$ before the end of the next decade if the present trend continues. Perhaps excluding that one upsurge in September in the high pollution zone, it can be stated here that the entire city experiences a similar trend of increase in ambient SO2 in both the zones.

Seasonality Characterestics of Ambient Oxides of Nitrogen (NOx)

With respect to NOx concentration, the fluctuations between the months shown in figure 4.9b could be explained more or less a similar way to the SO_2 fluctuations described above. There is a steady increase in ambient NOx concentration during January to May and a decrease during other months. It can also be seen that there is a phenomenal increase in NOx during the month of September. This can also be due to excessive humidity during this peak monsoon month in Bangalore. NOx also can form acidity

in the atmosphere.

Although the annual mean concentrations are well within the least permissible standard of 30 µg/m3, but the upsurge during the peak monsoon month of September in high pollution zones are alarming. It can also be observed from the seasonality trends that the increase is gradual but is not as severe as that of SO_2.

4.1.4 SUMMARY OF EVALUATION OF AMBIENT AIR QUALITY AND SELECTION OF ZONES FOR EPIDEMIOLOGICAL STUDY

From the presentation of the results of retrospective analysis of ambient air quality with reference to SPM, NOx and SO2 the following important points emerge.

(i) Airborne SPM concentration in the centrally located high pollution zone is remarkably high (above 200 µg/m3) and show the qualities of both chronic and acute exposures during the past years. This is emerging out of an analysis of non-compliance of stations and certain zones with respect to ambient air quality standards.

(ii) Ambient SO_2 concentration in the centrally located high pollution zone, nevertheless do not exceeed the yearly permissible standard (80 $\mu g/m^3$) during the retrospective period (1980 to 1987), but the general trend is alarming. This has been confirmed during prospective pollution study (1988 and 1989).

(iii) Ambient NOx concentration in the centrally located high pollution zone, also does not exceed the annual permissible standard (80 $\mu g/m^3$) but it follows a less severe trend to that of

SO_2 in a more or less similar fashion.

Considering these characterestics it is important to choose the subjects from the high pollution zone for assessing the health impact. It can also be hypothesised that subjects residing for the past five years will show the signs and symptoms of diseases likely to arise from the chronic and acute exposures to airborne SPM, SO_2 and NOx (see the theoretical model, fig 3.1).

An assumption can be made that a person residing at this zone experiences pollution exposure above an annual average standard concentration (SPM) which infact, in cumulative terms can add to chronic health impact. It is, therefore, thought appropriate to hold the health morbidity investigations mainly in the high pollution zone. Further, the estimates of integrated exposures or time weighted exposures of the sample can be carried out empirically accounting for a 24 hour exposure instead of considering only 8 hourly monitored values. In the subsequent sections the results and analysis of the epidemiological investigations are presented.

4.2 STAGE 2 - PROSPECTVE EPIDEMIOLOGICAL STUDY

The morbidity statistics as obtained from the two time epidemiological survey are described in the first two sections in general. In the subsequent sections the change in morbidity in the same sample as observed between the two periods of study is presented. Here the details of specific disease conditions and their dynamics of change are tabulated in a matrix form in order to establish the similarities among the groups. Further the groups are tested for differences in their exposure patterns using statistical methods such as analysis of variance (ANOVA). Finally inferences are drawn with regard to the association between the change in morbid states and exposure levels. The exposures tested are the cumulative chronic and acute exposures mainly in particulate matter.

4.2.1 RESULTS OF FIRST HEALTH MORBIDITY SURVEY

The morbidity statistics as obtained from two high pollution zones viz., Chamarajpet and Cottonpet divisions have been presented in table 4.4. The reported total morbidity (including all types of diseases) is 32.26 % and 38.84 % in Chamarajpet and Cottonpet divisions respectively. Out of these the respiratory type of diseases (International Code of Diseases, ICD: 10-12,and 460-519) reported are 15.93 % and 15.82 % . The Cardio-vascular diseases (heart and circulatory, ICDs are shown in the table) accounted for 3 % and 5 %. This means that out of the total morbid conditions, approximately fifty percent is found to be arising out of respiratory and cardio-vascular type of

diseases in both the divisions. There are just 1 % (3 subjects) of cancer cases found in only Cottonpet division.

Table 4.4a Statistics of general health morbidity, a comparison between the divisions and years of the study

Division : CHAMARAJPET

Year : 1988	(f)	(%)	Age(Yr) Mean	(SD)	Weight (kg) Mean	(SD)	Sex (%) Male	Female
1.0 NORMAL	337	67.7	28.2	12.9	47.8	12.1	40	60
2.0 MORBID	160	32.3	35.4	15.2	52.3	11.9	46	54
2.1 Respiratory	79	15.9	30.6	14.6	51.0	11.5	52	48
2.2 Heart	2	0.4	65.0	4.0	58.0	2.0	100	
2.3 Circulatory	13	2.6	50.5	7.2	59.3	6.2	38	62
2.4 Cancer								
2.5 Others	66	13.3	37.4	13.8	52.3	12.8	39	61
Year : 1989								
1.0 NORMAL	256	51.8	28.2	13.2	47.9	13.0	43	57
2.0 MORBID	238	48.2	34.2	15.6	52.1	12.2	42	58
2.1 Respiratory	139	28.1	29.9	14.6	50.2	12.3	47	53
2.2 Heart	1	0.2	60.0	0.0	65.0	0.0		100
2.3 Circulatory	4	0.8	44.5	10.4	56.3	5.8	50	50
2.4 Cancer								
2.5 Others	94	19.0	39.9	15.0	54.5	11.8	34	66

contd..

Table 4.4b Statistics of general health morbidity, a comparison between the divisions and years of the study

Division : COTTONPET

	Year : 1988	(f)	(%)	Age(Yr) Mean	(SD)	Weight (kg) Mean	(SD)	Sex (%) Male	Female
1.0	NORMAL	348	61.6	26.0	12.3	47.2	13.9	41	59
2.0	MORBID	221	38.8	33.6	15.6	51.1	15.4	42	58
2.1	Respiratory	90	15.8	30.6	16.3	46.6	14.9	49	51
2.2	Heart	4	0.7	42.3	11.6	45.5	0.5		100
2.3	Circulatory	23	4.0	49.1	9.0	59.7	8.3	35	65
2.4	Cancer	3	0.5	33.7	19.6	46.4	0.0	100	
2.5	Others	101	17.8	32.5	14.0	52.7	14.9	38	62
	Year : 1989								
1.0	NORMAL	366	64.4	27.6	13.1	48.3	14.7	51	49
2.0	MORBID	202	35.6	34.5	15.6	52.5	15.4	47	53
2.1	Respiratory	103	18.1	31.4	15.6	49.9	15.0	57	43
2.2	Heart	3	0.5	41.3	13.8	67.3	24.9	67	33
2.3	Circulatory	12	2.1	47.0	8.8	57.0	12.6	25	75
2.4	Cancer								
2.5	Others	84	14.8	36.3	15.3	54.1	14.8	36	64

[Note : International Code of Disease (ICD) for the disease type :

1.0	NORMAL	(0)
2.0	MORBID	(1-999)
2.1	Respiratory	(10-12, 460-519)
2.2	Heart	(393-398, 410-429)
2.3	Circulatory	(390-392, 400-404, 430-458)
2.4	Cancer	(140-239)
2.5	Others	(1-999, excluding (Sr.no. 2.1..2.4)

Blanks indicate insufficient data]

Some of the personal features of the subjects are also shown in the table 4.4.

It can be readily seen from this table that the mean age of the normal subjects is lower (26 yr and 28 yr) than those compared to total morbid coditions (39 yr and 32 yr). Among the subgroups, respiratory types indicate lower ages (31 yr) from both the divisions in comparison to cardio-vascular and other diseases. It is to be mentioned here that the present statistics refers to the persons with the ages above 10 years and do not include infants and children. Perhaps, it is to be noted that such groups are more suseptible to morbidity with respect to respiratory conditions.

Variations with respect to body weights of the subjects also indicate the characteristics of younger age groups as can be seen from the above mentioned table. Body weights vary between 51.01 kg (SD = 11.47) and 46.58 kg (SD = 14.95) in Chamarajpet and Cottonpet divisions respectively.

Another notable feature is the sex difference among the groups. Majority of the subjects are women i.e., 54 % and 58 % in morbid groups. But the respiratory diseases included under Chamarajpet division show 48 % as female, while in Cottonpet are 51 %. This marginal difference, perhaps is indicative of the morbidity of women arising out of exposure to domestic pollution. In Cottonpet division majority of households use kerosene and firewood as cooking fuels. Further the cardio-vascular diseases are also in line with respiratory showing higher morbidity (65 %) among women in Cottonpet division. In Chamarajpet division,

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Cardio-vascular morbidity with female group is 62 % and it is higher than respiratory morbidity of 48 %. This indicates that there is less association between these diseases. But in Cottonpet division this association is better where the female groups show higher morbidity in both respiratory (51 %) and cardiovascular (65 %) diseases.

As it was mentioned in Chapter 2, the exposure to SPM concentrations as experienced by the sample population are computed using empirical data. In figure 4.10 is shown the percent population against annual exposures (24 hourly averaging time) to SPM ($\mu g/m^3$) during 1988.

The permissible standards for SPM in case of 24 hourly averaging time are shown in table 3.1 (Chapter 3). In case of (i) sensitive, (ii) residential and (iii) industrial population they are prescribed to be 70 $\mu g/m^3$, 140 $\mu g/m^3$, and 360 $\mu g/m^3$ respectively. It can be observed, comparitively, that the annual exposures prescibed for sensitive and residential exposures have been exceeded in Chamarajpet and Cottonpet divisions in all respects. 94 % of the population sampled in Chamarajpet and 58 % in Cottonpet are within 360 $\mu g/m^3$, a maximum limit in case of industrial region. The rest of these i.e., 6 % and 48 % in the two divisions far exceed any permissible standards. Perhaps, the levels above 360 $\mu g/m^3$ reach upto 1900 $\mu g/m^3$ in extreme cases.

The present estimates of SPM exposures are only conservative figures, because the computations are based upon the ambient monitoring data from stations situated abovt half a kilometer distance. But the estimates of exposures during year

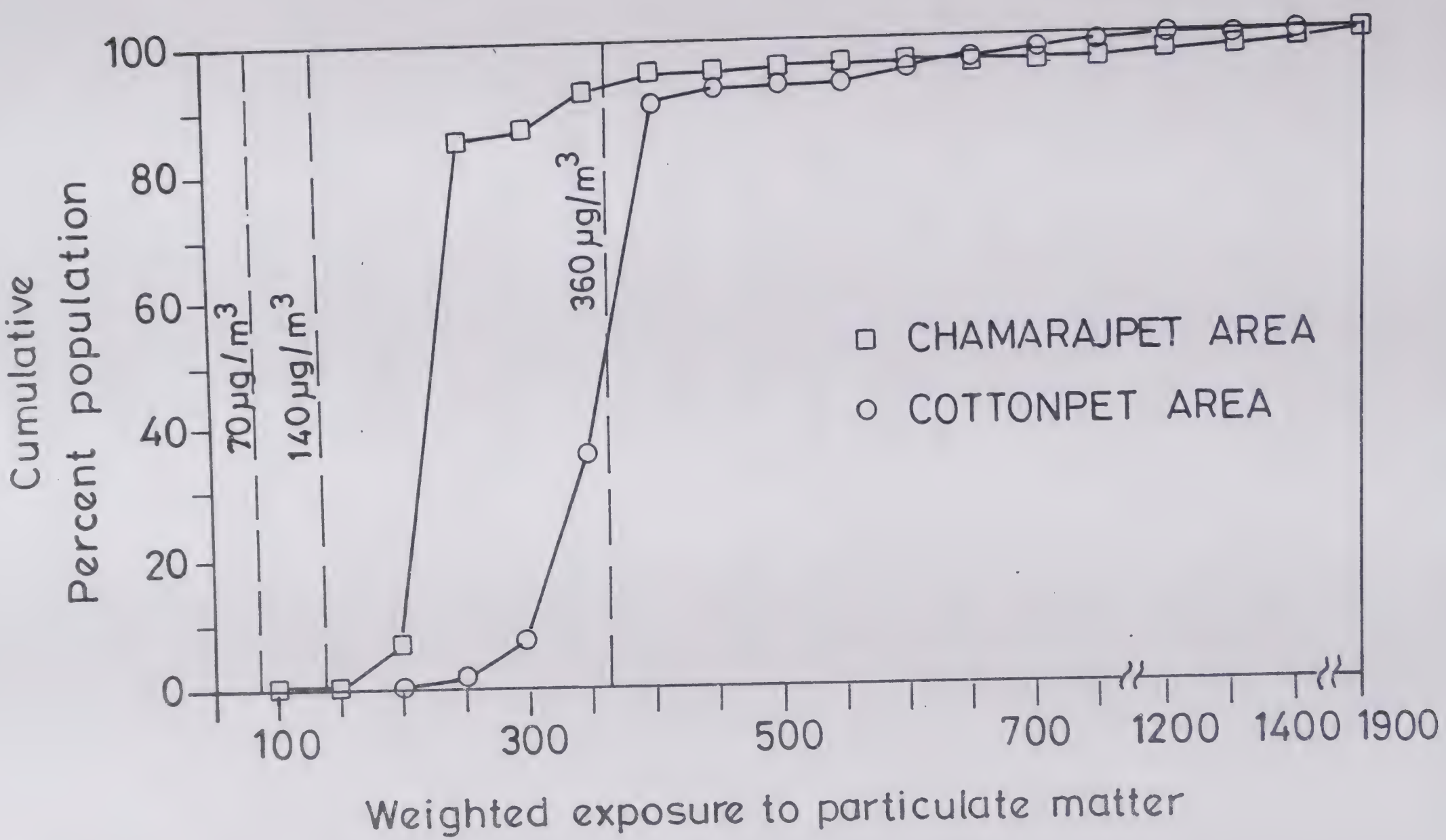

FIG. 4.10 PERCENT POPULATION DISTRIBUTION AGAINST EXPOSURES (SPM-1988).

1990 are based upon the stations situated right in Chamarajpet and Cottonpet divisions.

4.2.2 RESULTS OF SECOND HEALTH MORBIDITY SURVEY

The statistics of general morbidity as obtained during the Second epidemiological survey is also presented in table 4.4 for Chamarajpet and Cottonpet divisions. It is to be mentioned here that attempts were made to generate the information from among the same households which were surveyed in the first investigation a year earlier.

It can be seen from the table 4.4 that the total morbid cases account for 48.18 % and 35.56 % from Chamarajpet and Cottonpet divisions which are comparitively higher from the first study conducted one year before. This can be attributed to various reasons. (i) There were some subjects not available at the time of second survey and are excluded. (ii) There were subjects who had shown symptomatic conditions with unconfirmed diagnosis in the first survey but confirmed as diagnosed cases in the second. (iii) There was also a general increase in morbidity. Considering these, it can be noted here that while evaluating the change in morbidity only the subjects available during the two time periods are chosen (see section 2.2.3).

It can be observed readily that out of the total morbid cases in 1989, 28.14 % and 18.15 % are reported to be from respiratory type of diseases (see table 4.4) in Chamarajpet and Cottonpet divisions respectively. This however, accounts for nearly 50 % of total morbidity in relative terms similar to that

of 1988 survey. But,it is apparent from table 4.4 actual increase is seen in Chamarajpet in both total number of morbid cases vis a vis in the sub-group of respiratory diseases. In Cottonpet the situation remained more or less the same in both years.

The personal features with respect to age (in years), weight (in kg) and sex differences among the two divisions and the two periods are comparable.

The mean age among the morbid subjects are shown to be 34 yr (SD = 16) and 35 yr (SD = 16) in 1989, 35 yr (SD = 15) and 34 yr (SD = 16) in 1988 in Chamarajpet and Cottonpet divisions respectively. In case of respiratory subjects the mean ages are 30 yr (SD = 15) and 31 yr (SD = 16) in 1989, 31 yr (SD = 16) and 31 yr (SD = 16) in 1988 respectively from Chamarajpet and Cottopet divisions.

The weight (in kg) of the subjects under the respiratory type of diseases are 50 (SD = 12) and 50 (SD = 15) in 1989, 51 (SD = 11) and 47 (SD = 15) in 1988 in Chamarajpet and Cottonpet divisions respectively.

With reference to sex differences, the women at Cottonpet show a decrease from 51 % to 43 % in respiratory diseases but an increase in Cardio-vascular diseases from 65 % to 75 % between 1988 and 1989. Whereas, in Chamarajpet an increase from 48 % to 53 % in respiratory diseases and a decrease of 62 % to 50 % in Cardio-vascular diseases. This indicates the possible change in health conditions of subjects surveyed two times with a gap of one year period.

The above differences with respect to personal features

are shown to indicate the regional differences in Chamarajpet and Cottonpet divisions. These two divisions infact represent predominance of residential and commercial communities respectively. It is likely that the differences are mainly due to economic conditions and allied factors such as years of stay as well as habits (e.g.,smoking) of the communities as can be seen below:

NO.	State	Annual Income (%)			Years of stay (%)				Smoking (%)	
		Low	Mid	High	5	10	15	20	Yes	No
CHAMARAJPET DIVISION										
1.0	NORMAL	65	27	8	24	18	14	44	7	93
2.0	MORBID	63	29	8	17	20	12	51	11	89
COTTONPET DIVISION										
1.0	NORMAL	91	7	2	15	11	6	68	6	94
2.0	MORBID	90	10	1	10	10	6	73	15	85

In Chamarajpet division majority of the subjects belong to middle class (27 % to 29 %) and lower middle class (63 % to 65 %) income groups as can be seen from above. Middle class had annual incomes per house-hold between a range of Rs.20,000 and Rs.40,000. Whereas, the lower and the rich are at the extremes (low: Below Rs.20,000, Rich : Above Rs.40,000). The years of settling in the zone are quite interestingly distributed as can be seen above. The subjects belonging to morbid groups have stayed comparitively longer periods (51 %) say, for 20 years in the communit

In Cottonpet division, the subjects living in the community belong to lower income group (mostly the working group with annual house-hold income of Rs.20,000 and below) accounting for 90 % to 91 %. Further, about 68% to 73% had their stay in this division in the last 25 years. There is only a slight difference in smoking patterns between the two divisions.

4.2.3 RESULTS AND ANALYSIS OF CHANGE IN MORBIDITY BETWEEN THE TWO MORBIDITY STUDIES

As explained in section 3.3.2 (Chapter 3) a transition matrix was generated with reference to change in the health states of the subjects between 1988 and 1989 and the same is shown in table 4.5. A health condition of a subject here can be stated to be based upon the diagnosis given by the doctors at the time of medical examination and clinical tests. Accordingly, the normal subject (group 1) is referred to as the person being stated as "not having abnormality with respect to any disease conditions what so ever".

Further, the diagnoses of diseases are compiled with a standard format as referred under the classifications of International Code of diseases (ICD). This has also been shown in table 4.4 describing the vital statistics generated in the study zones.

In the present analysis, the diseased subjects are grouped under a broad classification of mode of affliction and toxicity affecting the organs and the systems of the body. The upper (group 2) and the lower (group 3) respiratory diseases (URI and LRI) are refered to as extra-thoracic with tracheo-bronchial

and pulmonary infestations respectively. The implicit bifurcation of respiratory system in to URI and LRI is adopted with an assumption that the particles (airborne and SO_2) show afflictions of respiratory organs based upon their size. The finer particles of size 4 micro-m and below, perhaps enter the deeper parts (pulmonary region, See Chapter 2, section 2.2.1.1, Nature and Impact of Smoke Density on Human Body) in appreciable quantities.

The diseases of the heart and the circulatory (CVS, group 4) system are in line with respiratory diseases because of a closer association between the two systems. Continued lower respiratory diseases can have serious perturbations on cardio-vascular performances. Group 5, skin and Subcutaneous diseases is the peripheral diseases of human body. Groups 6, 7, 8 and 9 belong to Central Nervous system, Metabolic and hormonal, infections and gastro-intestinal placed on priority basis. Group 10, includes others, meaning diseases arising out of non-environmental causes. Group 11, includes combinations between the 9 groups excluding the normal group as stated above.

It can be seen from this table (table 4.5) that the cells confined to first nine rows and the corresponding columns are referred to be in the purely single state of health conditions affecting the physiological systems as shown in the table. The tenth includes the diseases of non-environmental origin or in otherwords, most of the physical injuries and fractures of bones are included under these. The 11th row and corresponding column is referred to be combinations of all diseases under the present conditions. These however, were not been separated from the

others because of the real difficulty arising out of confounding factors.

In table 4.6 is shown the probabilities expressed in percentage of change ensuing 1989 among the combinations. It can be observed from the first row that the subjects remaining normal during 1988 and 1989 are 84 %. Out of the remaining, (in first row) 7 %, 1 % and 2 % are the incidental groups showing fresh morbidity in 1989. These belong to Upper respiratory, Lower respiratory and Cardio-vascular diseases respectively. The 11th column indicates 2 % of diseases of "combinations" arising from the normal group. (Note that the values in % are shown without decimal points to enhance comprehension.) The subjects confined to the first row are a group moving from "Normal to Disease" condition which infact, is the incidence of morbidity noticed in the year 1989.

It may not be out of place to mention that such data governing a gap of one year perhaps, may be insufficient from the point of establishing the trends in incidence of morbidity. It is implicit to say that there is a definite need for data from year after year in order to generalise the epidemiological information.

The values present in the diagonal of the matrix (table 4.6) from 1 to 11 are those subjects remaining in the same states ("Same condition both years") in 1988 and 1989. This set infact, shows the prevalent conditions of morbidity in the community. It constitutes 16.3 % of the grand total.

Table 4.5 Change in the subjects' condition between 1988 and 1989

HEALTH STATE	YEAR/ Sr.no.	1989 1	2	3	4	5	6	7	8	9	10	11	12	TTL
1988														
NORMAL	1	642	59	6	14	1	9	2	1	2	11	19		766
URI	2	15	45	4					1	1		5	1	72
LRI	3	9	5	32	2			1				8		57
CVS	4	7	1	2	26	1				1	1	12		51
SKIN	5	4				1	1					2		8
CNS	6	7	2		1		6			1	1	6		24
METABOLIC	7	8	1	1			1	13		1	1	6		32
INFECTIOUS	8										1			1
GI	9	1								11		3		15
OTHERS	10	3	2		1						6	1		13
COM (2..10)	11	14	4	4	1		1	1				40		65
TOTAL (1..11)		710	119	49	45	3	18	17	2	17	21	102	1	1104

(Note: Sr.no. 12 represents mortality)

4.6 Transition probability matrix (Probality in percentage)

HEALTH STATE	YEAR/ Sr.no.	1989 1	2	3	4	5	6	7	8	9	10	11	12	TTL
1988														
NORMAL	1	84	7	1	2		1				1	2		100
URI	2	21	63	6					1	1		7	1	100
LRI	3	16	9	56	4			2				14		100
CVS	4	14	2	4	51	2				2	2	24		100
SKIN	5	50				13	13					25		100
CNS	6	29	8		4		25			4	4	25		100
METABOLIC	7	25	3	3			3	41		3	3	19		100
INFECTIOUS	8										100			100
GI	9	7							73			20		100
OTHERS	10	23	15		8						46	8		100
COMBINED (2..10)	11	22	6	6	2		2	2				62		100

Subsequently, the values below the diagonal indicate the movement of subjects from a higher order disease to lower order disease ("D2 to D1"). Where as, those above the diagonal are the movements from lower order to higher order ("D1 to D2").

The following table shows the frequencies and

percentages confining to the above described combinations named after "transition groups".

Table 4.7 Analysis of Transition Groups and their frequencies

Code/ sr.no.	Change in Health State (between 1988 and 1989)	Number of Subjects (f)	(in %)
0	Normal to Normal (NAD)	642	58.2
1	Diseased (Di) to Normal	68	6.2
2	D2 to D1	28	2.5
3	D1 to D2	61	5.5
4	Normal to Diseased	124	11.2
5	* Same both year	180	16.3
6	Mortality	1	0.1
(1..6)	Total	462	41.8
(0..7)	Grand Total	1,104	100.0

(Note : * "Same both year" includes 41 (3.6 %) subjects from 1988 who were in the symptomatic group left out as undiagnosed cases till the second study, 1989)

It can be seen from table 4.7 that the subjects belonging to same disease group in both the years are 16.3 % of the total. Those moved from normal to diseased are 11.2 % and from lower order to higher order disease are 5.5 %. These three groups show "undesirable directions of movements" from community health point of view. But those moving back from diseased to normal, and higher order to lower order of diseases are quite low i.e., 6.2 % and 2.5 %. Unfortunately, these are the "desired direction of movements".

One of the major objectives of the present study is to

investigate the exposure characteristics with reference to the disease transition groups mainly. The same have been presented in section 4.2.5. The future trend in morbidity are predicted using Markov Analysis as shown below.

4.2.4 MARKOV ANALYSIS OF MORBIDITY

A total number of 135 morbid classifications have been used in the actual diagnostic studies. For the purpose of this analysis, these were initially grouped into 11 states, and a transition matrix was generated.

The sum of every row of this matrix gives the total number of persons having the morbid conditions indicated by the row in 1988. For example,in the case of Upper Respiratory Disease the total number is 71. Each cell in a row is divided by the row total to get the probability of the transition indicated by the cell. For example, probability of transition of a person from Upper Respiratory to Lower Respiratory is o.56 given by the cell (2,3). The whole probability matrix is generated in this manner.

The transition probability matrix was simplified by grouping classifications 5 to 10 into a single one and finally the transition matrix shown in table 4.8 was developed. This is a simplified version of our data and we concentrate only on the major morbidity classifications. The matrix represents how the people are going to transition from one morbid condition to another in a years time given the the existing conditions of pollution, medication and habits of the subjects in the sample chosen, and may represent reasonably the population of the high

risk zone from which they are drawn.

The steady state probabilities of morbidity which can be expected in the long run, if derived from this matrix will now give us the steady state morbidity vector which is independent of the initial vector i.e., whatever was the morbid condition of the sample in 1988. The steady state probability matrix

Table 4.8 Transition probability matrix (Probability in percentage)

MBD STATE	YEAR/ Sr.no.	1989 1	2	3	4	5	6
	1988						
NORMAL	1	0.8381	0.0663	0.0072	0.0170	0.0339	0.0248
URI	2	0.2083	0.6250	0.0556		0.0282	0.0704
LRI	3	0.1579	0.0877	0.5614	0.0351	0.0175	0.1404
CVS	4	0.1373	0.0196	0.0392	0.5098	0.0588	0.2353
OTHERS (5..10)	5	0.2473	0.0538	0.0108	0.0215	0.4731	0.1935
COMBN	6	0.2222	0.0635	0.0635	0.1590		0.6349

Matrix Raised to Power 17

1	0.5611	0.1642	0.0549	0.0315	0.0502	0.1377
2	0.5606	0.1643	0.0551	0.0315	0.0502	0.1380
3	0.5604	0.1642	0.0553	0.0315	0.0502	0.1383
4	0.5604	0.1641	0.0552	0.0315	0.0502	0.1383
5	0.5607	0.1642	0.0551	0.0315	0.0502	0.1380
6	0.5606	0.1642	0.0552	0.0315	0.0502	0.1381

obtained by exponentiating the matrix (17 years in this case) is

also shown in table 4.8. From this table it can be seen that 56 % o the population will be healthy, 16 % will suffer from URI, 5 % from LRI, 3 % from CVS and 5 % from others individually, and 13 % from combinations, if the results of the sample can be thought of as representing in the population. Thus in the long run we may expect 21 % of the people to have respiratory diseases.

The foregoing results are not conclusive but only indicative and can only be ratified if similar studies are continued over longer periods of time.

It is to be noted that the data has been slightly adjusted to eliminate the single mortality case found in 1989 and information on the details of diseases 5 to 10 in the table are lost. However, the general results of the more important morbid conditions remain unaltered.

MORBIDITY RATING BY DOCTORS AND PATIENTS

As indicated in methodology (Chapter 2) a opinion survey was conducted among the subjects and also the doctors as to the symptoms, signs and diseases. They were asked to rate whether the conditions with respect to these are better, same or worse compared to the previous visit during 1988. A good correlation ($r = 0.96$) between the subjects' rating and doctors' rating was observed, in otherwords their opinions were very closely associated in most of the conditions.

Table 4.9 Morbidity rating by doctors and subjects (%)

OPENION	MUCH BETTER	BETTER	SAME AS BEFORE	WORSE	MORE WORSE
CATEGORY	1	2	3	4	5
DISEASE TO NORMAL	4	10	84		1
D2 TO D1		12	39	49	
D1 TO D2		8	39	50	3
NORMAL TO DISEASE		2	39	58	
DISEASED BOTH YEAR		11	45	42	2

The results of these opinions in percentages of population in the transition groups are shown in the table 4.9.

It can be observed from this table that 84 % of the subjects who had transition from diseased to normal states felt that they had the same difficulties as they had in 1988. Only 10 % expressed as better as can be seen from the first row in the table. Among those who felt worst symptoms and signs from the previous year are 58 % shown in case of group "normal to diseased". In the same group 39 % felt same as before.

In total, the majority of cases are undesirable transition groups (Normal to diseased, D1 to D2, and diseased both year) 39 % to 45 % felt that their conditions were same as before. 42 % to 50 % expressed worse feeling, and 2 % to 3 % felt much worse.

Those who felt better among the desirable transition groups were only 10 % and 12 % . Further, only abovt 4 % in the group diseased to normal felt much better.

4.2.5 VARIATION IN WEIGHTED EXPOSURES TO SPM AMONG THE TRANSITION GROUPS

The cumulative percentage of population distribution against the weighted exposure concentration in SPM are plotted first, for the diseased and normal group. The same have been shown in figure 4.11. It can be seen from this figure that the population exposures between the various concentrations are almost similar except for a marginal difference. For example, at exposure concentration of 400 $\mu g/m^3$ the percentage population in diseased group is 72 % and in normal group it is 68 %.

Further, a similar cumulative percent population distribution against exposure to SPM from the previous year's (1988) data are superimposed as can be seen from figure 4.12. It is to be mentioned that the estimates of exposures in 1988 are derived by using the ambient SPM data from nearby monitoring stations unlike in 1989 estimations of exposures. It is because in 1989, two ambient stations were located in Chamarajpet and Cottonpet divisions in the vicinity of test groups.

It can be readily observed that there are larger differences between the 1988 and 1989 exposures for the same group of subjects. The same can be first evaluated from the permissible exposure points of view. At a permissible standard of 70 $\mu g/m^3$ the disease sensitive standard has been exceeded by the groups during both years. At a level of 140 $\mu g/m^3$ (residential limit) about 92 % exceeded the prescribed standard in 1988, while the entire groups exceeded this limit in 1989. At the maximum

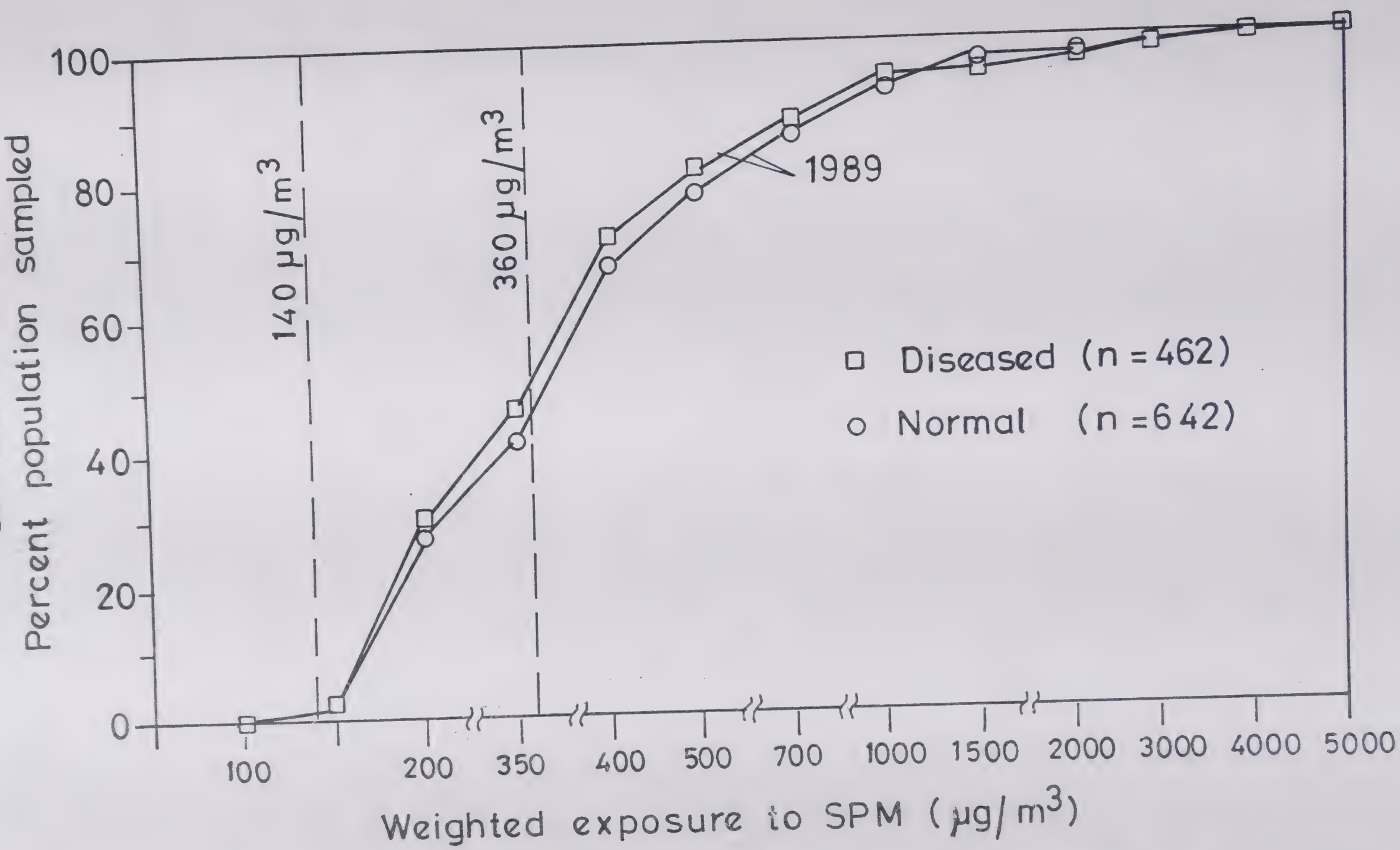

FIG. 4.11 PERCENT POPULATION DISTRIBUTION AGAINST EXPOSURES (SPM).

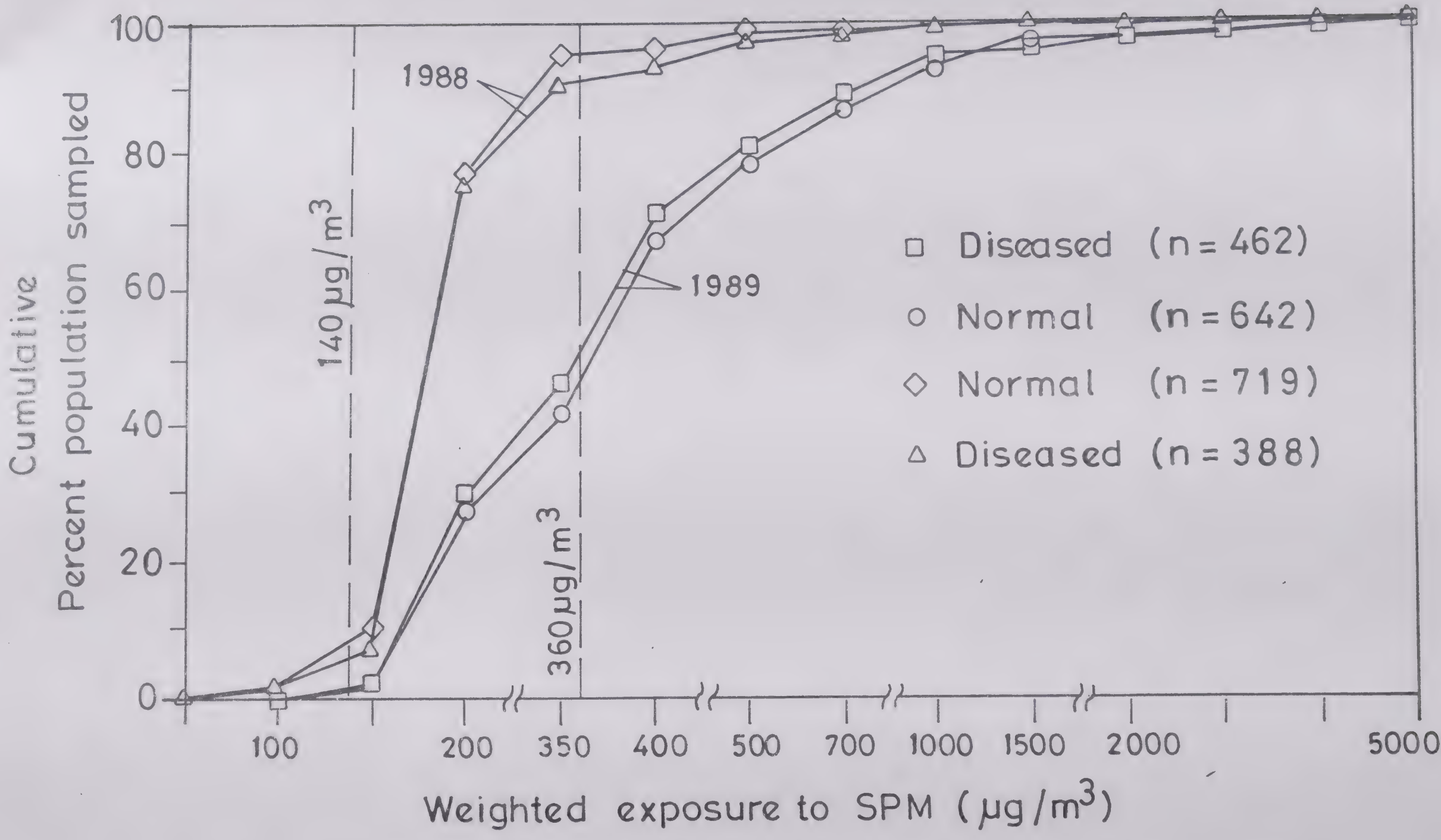

FIG. 4.12 COMPARATIVE POPULATION DISTRIBUTION AGAINST EXPOSURES (SPM) IN 1988 & 1989.

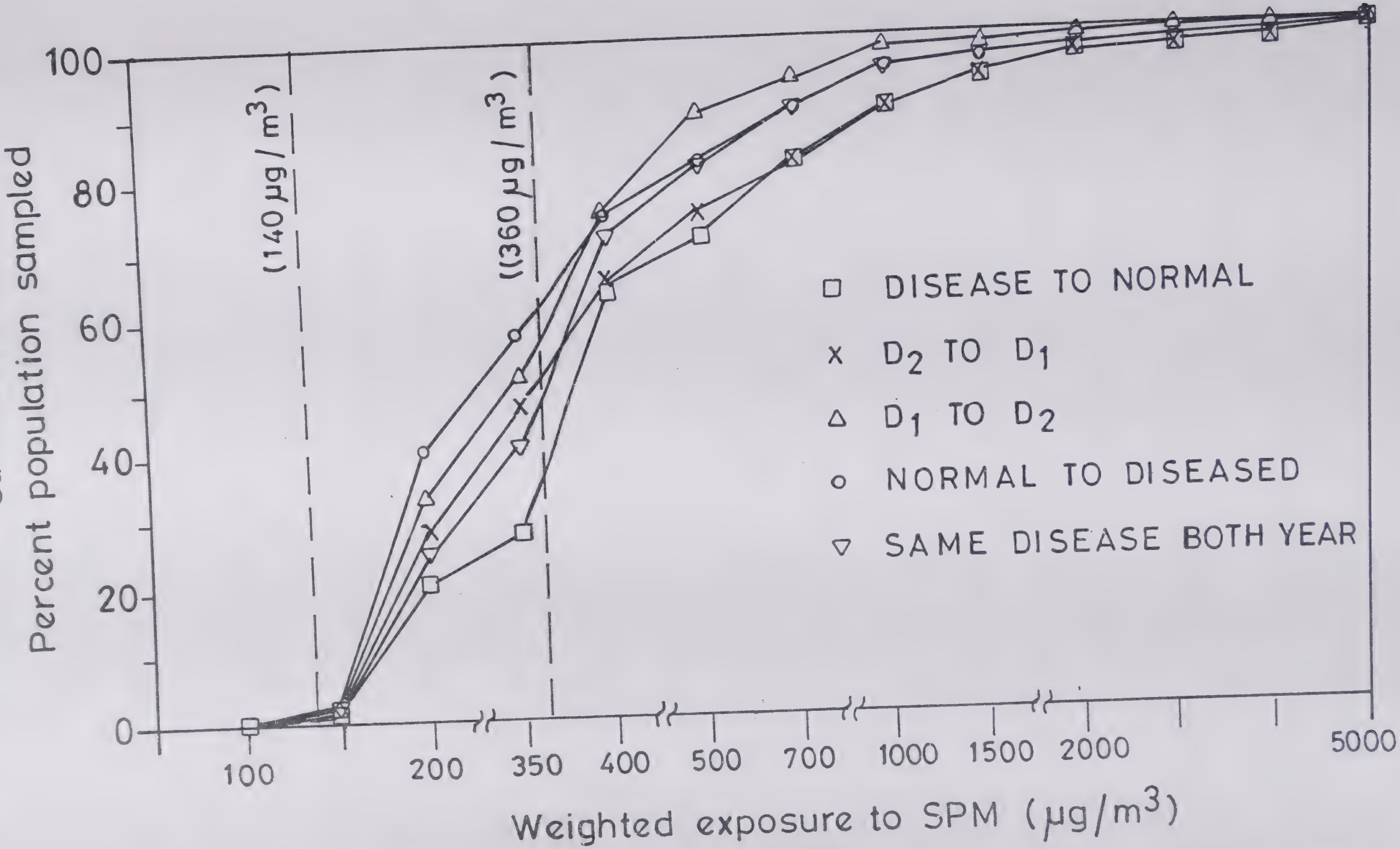

FIG. 4.13 PERCENT POPULATION DISTRIBUTION AGAINST EXPOSURE (SPM) AMONG TRANSITION GROUPS.

prescribed limits of 360 $\mu g/m^3$, about 5 % and 45 % exceeded the limits between 1988 and 1989. It indicates also the severity of exposure experienced by the two groups in 1989 compared to 1988.

In figure 4.13 are plotted exposure versus percentage population for the disease transition groups. From this figure there appears to be differences among the number of persons exposed to varied exposure concentrations. These differences appear larger between 200 $\mu g/m^3$ and 300 $\mu g/m^3$ levels. At a level of 360 $\mu g/m^3$ the group described as moving from disease to normal condition show 65 % of non-compliance while among the normal to diseased as 35 %. The rest of the groups are between these two extremes. The discrepency of larger numbers experiencing compliance at 360 $\mu g/m^3$ among the undesirable directions of movements can arise because of insufficient number of subjects present in the groups showing desired direction of movement.

Considering these set backs presented during the field ionvestigations, the data at various levels of standard limit are tested for real differences, if any, among the transition groups by considering the total annual exposures as described below.

4.2.6 ANALYSIS OF THE CUMULATIVE EXPOSURE

The activity time weighted exposures (SPM) on typical days in 52 weeks period which intervenes between 1988 and 1989 morbidity investigations are generated using the models and methods mentioned in sections 3.3. The same are cumulated for the entire 52 weeks period according to the individual subject. The tota

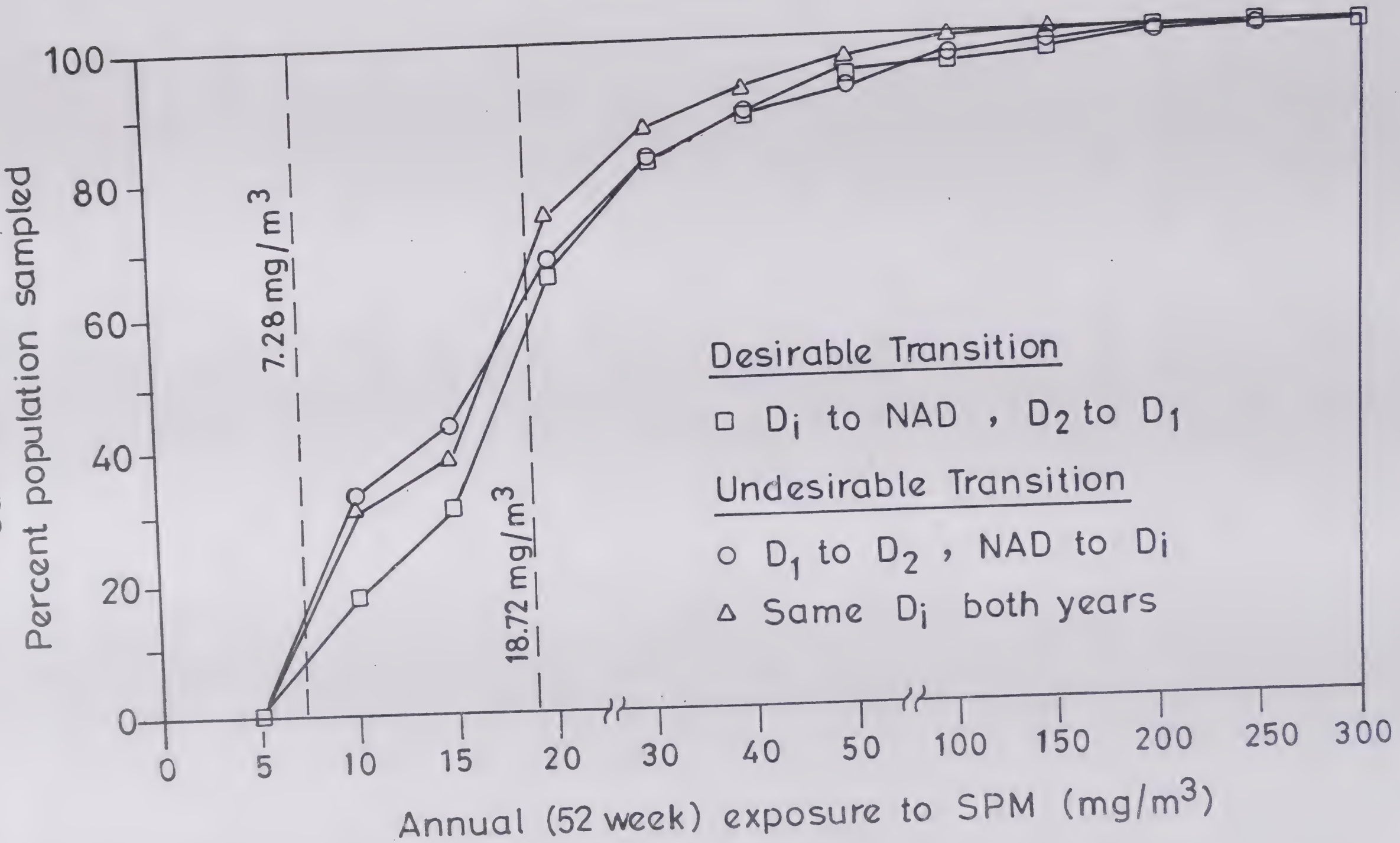

FIG. 4.14 PERCENT POPULATION DISTRIBUTION AGAINST EXPOSURE (SPM) AMONG TRANSITION GROUPS.

exposures are expressed in terms of mg/m^3-week. A plot showing the percentage distribution of the three groups (undesirable I, II and desirable III) against the cumulative concentrations by weeks are shown in figure 4.14. At a permissible level of (360 x 52) there are some interesting changeover of the curve path especially in case of diseased subjects during both the years. However the differences seemed to be only marginal.

In order to test the real differences among the cumulative exposure in transition groups methods of analysis of variance are used (ANOVA, Ramdomised design). The levels are tested at 75 % and 90 % confidence limits.

In the final analysis four types of cumulations expressed in terms of µg/m^3-week are tried viz.,

(i) Cumulative exposure (total),

(ii) Cumulative exposure above residential permissible standard (24 hourly) i.e., 140 µg/m3,

(iii) Cumulative exposure above residential permissible standard (8 hourly) i.e., 200 µg/m3,

(iv) Cumulative exposure above the industrial permissible standard (24 hourly) i.e., 360 µg/m3,

(v) Cumulative exposure above the industrial permissible standard (8 hourly) i.e., 500 µg/m3.

The variation in these exposure estimates are tested for differences between the transition groups as presented in table 4.8. It can be noticed from this table that as the iteration continued from (i) to (v) there is a gradual elimination of certain subjects in the group. These subjects had lower magnitude of exposure. In otherwords, the same can be interpreted that as

the magnitude of exposures became severe there was a shift observed from the characteristics of chronic exposure to that of acute exposure. Perhaps, the subjects experiencing intense exposures were however got segregated from the others experiencing less exposure in terms of acuteness.

In clear terms the total cumulative exposures are treated as chronic exposures because of continuous exposure data. However, the acute exposures are the values above the permissible limits which are clearly delineated from the continuous exposures.

In terms of the actual differences between the groups tested at significance levels $P \geq 0.25$ and $P \geq 0.10$ there were no strong differences seen. However, it can be observed that the groups tested at cumulative exposures above 200 $\mu g/^3$ -week and 360 $\mu g/m^3$ -week the F-ratios (1.35 and 1.47 shown in table 4.8) at $P \geq 0.25$ showed significant differences. This suggests that the cumulative acute exposures show differences in their cumulative acute exposures to SPM. This perhaps indicate a possible concurrence with morbidity compared to those experiencing total cumulative exposure. These concurrences can only be treated as associations assuming that the particulate matter concentration exceeding the limits give rise to the risk in morbidity (see literature on acute exposure to particulate matter and Sulphur dioxide).

Further, the mean cumulative exposures of the groups are sorted in the descending order and shown in table 4.8. The

TABLE 4.8. Variation in Cumulative Exposure (SPM, $\mu g/m^3$-week) Tested for Differences in Transition Groups

"CUMULATIVE EXPOSURE (ug/m3)"	GROUP CODE	(n)	MEAN	SD	F-RATIO (P= 0.25)	F-RATIO (P= 0.1)
(i) "TOTAL"						
DISEASE TO NAD	1	68	27987	27589		
SAME BOTH YR	5.1	98	27111	32855		
NAD TO DISEASE	4	124	23440	37067	(1.07)	(1.07)
NAD BOTH YR	0	642	23363	23364	NS	NS
SYMP TO DISEASE	5.2	41	21038	12314		
DIS 1 TO DIS 2	3	89	20841	22124		
DIS 2 TO DIS 1	2	41	19105	13919		
(ii)"ABOVE 140"						
DISEASE TO NAD	1	68	20567	27589		
SAME BOTH YR	5.1	97	19895	32962		
NAD TO DISEASE	4	121	16431	37431	(1.09)	(1.09)
NAD BOTH YR	0	635	16124	23428	NS	NS
SYMP TO DISEASE	5.2	41	13618	12314		
DIS 1 TO DIS 2	3	89	13421	22124		
DIS 2 TO DIS 1	2	41	11685	13919		
(iii)"ABOVE 200"						
NAD TO DISEASE	4	73	22875	45703		
SAME BOTH YR	5.1	73	22641	36080		
DISEASE TO NAD	1	54	22276	29023	(1.34)	(1.34)
NAD BOTH YR	0	467	18102	25411	S	NS
DIS 1 TO DIS 2	3	55	17433	25624		
SYMP TO DISEASE	5.2	37	11716	12300		
DIS 2 TO DIS 1	2	31	11648	14687		
(iv)"ABOVE 360"						
NAD TO DISEASE	4	47	24746	54214		
SAME BOTH YR	5.1	51	21766	40840		
DISEASE TO NAD	1	45	16990	30797	(1.47)	(1.47)
NAD BOTH YR	0	313	15967	28927	S	NS
DIS 1 TO DIS 2	3	35	15678	30064		
SYMP TO DISEASE	5.2	18	8525	15852		
DIS 2 TO DIS 1	2	17	7909	17696		
(v) "ABOVE 500"						
NAD TO DISEASE	4	21	45460	71692		
DIS 1 TO DIS 2	3	12	35173	39081		
SAME BOTH YR	5.1	27	32390	49558	(0.64)	(0.64)
DISEASE TO NAD	1	19	31310	37752	NS	NS
DIS 2 TO DIS 1	2	3	28911	29671		
NAD BOTH YR	0	134	27244	36559		
SYMP TO DISEASE	5.2	5	18454	21682		

(Note : NAD = NORMAL, DIS1 = lower order disease, DIS2 = higher order disease, S = significant, NS = Not significant)

magnitudes of cumulative acute exposures at 200 $\mu g/m^3$-week and 360 $\mu g/m^3$-week are in the order of "undesirable to desirable direction" of transition. It may not be out of place to recall the earliar hypothesis that the subjects showing morbidity predominantly of respiratory type arise out of cumulative acute exposures (peak concentrations). In the present analysis there are indications to show that this hypothesis may be true.

In conclusion it can be stated that the magnitude of exposures giving rise to acute concentrations are significant and are detrimental to general health conditions tested in the high pollution zones. There seems to be insufficient data with respect to morbid groups because the present study is limited to a small population.

It can be stated that the present prospective study be extended further for few more years, it may be possible to assess the impact of pollution on health morbidity with greater assurance because of reliability arising out of larger data.

Other cumulations with respect to SO_2 are not tried in this study. But the air quality data with respect to SO_2 during the prospective period of the epidemiological study showed a rising trend. It is likely that there are similar associations between SO_2 and health morbidity.

In Chapter 5, the inferences and salient points emerging out of the present study have been summarised along with concluding remarks.

CONCLUDING REMARKS

CHAPTER 5

CONCLUDING REMARKS

Summarising briefly, from the present investigations of this study following salient features and important conclusions emerge.

To begin with, the need and relevance for conducting the present type of investigations in line with Environmental Epidemiological Studies were adequately emphasised. It is perhaps, the recent literature on air pollution episodes and natural calamities that inspires researchers, scientists, technologists, and environmental engineers to venture into the task of finding solutions for pollution problems on the one hand, and at the same time, keep the productive activities related to development active on the other hand, to the tune of maintaining economic stability in the region.

Although, in the present study, the literature review was focussed especially on pollutants of episodic nature viz., SPM or TSP (or smoke density), SO_2, and NOx, the nature of exposures of population to them such as chronicity and acuteness was attempted for investigations with particular reference to Bangalore city's population.

In actual terms, a two stage-research design was adopted to investigate the concurrence and association of the air quality status in relation to health morbidity. The literature and data available from secondary sources, was the ground work for the investigations. The methodology of carrying out

analysis of retrospective air quality data for the city (Stage 1 study), and derivation of spatial and seasonal distribution patterns of SPM, SO_2 and NOx is an important land mark of the present study. Though the secondary data collected refers to the period between 1980 and 1987, the primary data of our study updates the information upto 1989. The task has infact completed almost the task of understanding the prevailing air quality status the last decade (1980-1989) with refernce to SPM, SO_2, and NOx. It gives a signal for the future workers in the area to be alert and active, because the pollution trends in the city are not in favour of good air quality in future. It is especially significant in the case of SO_2 and NOx where there is a clear upsurge of these pollutants from 1980 to 1989. But, considering the comparison between the prescribed permissible standards and the prevailing SO_2, and NOx levels till 1987, it can be inferre that the retrospective period witnessed "the within permissible limits of exposure" in the city.

This was not so in the case of SPM. Although the upsurge was not significant, the level appears to have been stabilized and saturated for the road conditions and vehicular density in the city. This was found very much so in areas of high density population where the levels were beyond permissible limits. The heart of the city in fact, namely the commercial region appears to be emerging as the pollution

risk prone zone, in the city, from the pollution exposure. The disease sensitive people frequenting or staying in the zone can easily become susceptible to exposures. Nearly an area covering 21 square kilometers in the central and south central region of the city was found experiencing non-compliance with the residential permissible limit. Considering this aspect, and also from the sporadic information that was available in the case of health morbidity, a prospective epidemiological investigation was felt necessary and therefore a study in this direction was undertaken in this zone.

The yardsticks used in the study to carry out such evaluations were the prescribed pollution standards by the Central Board for Prevention and Control of Pollution in India. It was adequately clear from the available literature on acute and chronic exposure data that these prescribed levels are only fractions of episodic thresholds of 1000 $\mu g/m^3$ of SPM and SO_2. However, these standards refer to 8 hourly and 24 hourly average exposure time. The exposures will have disastrous impact, if the high levels continue at a stretch for 4 to 5 days in one dose. Further, from the equipments used in determining the SPM in Bangalore city, and the low wind blowing patterns in general throughout the year (except during pre-monsoon period) it can be inferred that the particulate sizes belong to fine category of 4 micro-meter and below. This is because of the reason that still winds allow settling of coarse particles rapidly. The fine particulate matter is 50 times more dangerous than coarse particles. Because the particles could enter the deep

pulmonary region in the respiratory system they cause injury and toxicity in the human body. There were adequate evidences of these in the Stage 2 study, which includes the prospective epidemiological study held in high density and high pollution region.

A sample population of 1500 subjects from among the Chamarajpet and Cottonpet divisions were chosen for health morbidity studies at two points in time, i.e., during October to December 1988, and again during October to December 1989 with an intervening gap of one year (52 weeks). The health data with reference to these indicate that there are linkages between the transitions of diseases from lower respiratory tract infestations to cardio-vascular type of diseases. For example, the two years data in Cottonpet division in the same group of samples indicate that the women had a decrease from 51 % to 43 % of morbidity in respiratory diseases. There was a reversal trend of increase from 65 % to 75 % morbidity in case of same samples in cardio-vascular type of diseases. It is important to note that Cottonpet region is a commercial locality with communities belonging to lower income groups. Nearly 90 % had an annual income below Rs 20,000 or less. These people generally used kerosene as their prime fuel in the kitchens, sometimes followed by firewood and electricity. It was interesting to note that in Chamarajpet division where 63 % belonging to lower income groups and 29 % to the middle income groups used Liquified Petroleum Gas was the major fuel. In terms o

transitions in morbidities between respiratory and cardio-vascular diseases there was an increase of 48 % to 53 % of morbidity due to respiratory diseases, while a decrease of 62 % to 50 % in cardio-vascular diseases. This reversal of trend among the two dissimilar communities indicate the severety of pollution impact in Cottonpet region.

Finally the transitions among morbid conditions between 1988 and 1989 were analysed. Subjects from both the divisions were pooled and those found during both the periods of epidemiological studies only were used for transition analysis. This group constitutes 1104 subjects with one unfortunate case of mortality in the respiratory type of disease. Out of a total combinations of 78 x 136 types of diseases, a transition matrix of 11 x 11 combinations of disease "states" were obtained. This classification was evolved through prioritising the pollution prone diseases under separate groups. In all the disease groups like Upper Respiratory, Lower Respiratory, Cardio-vascular, Skin, Nervous system, Metabolic, Infectitious and Others plus the Combinations were derived and enumerated in a descending order of infliction due to air pollutants like particulate matter and SO_2.

In the subsequent analysis, greater emphasis was laid on identifying the groups of subjects showing the desirable and undesirable directions of movements between the two morbidity studies. Finally, these groups were treated for a comparitive analysis of cumulative frequency distribution against integrated exposures to SPM concentrations. These exposures

infact relate to personal exposures of the subjects in all respects. They were derived from an empirical survey on various micro-environments in the activity zones of the subjects. Clear differences emerged in the exposure concentrations in SPM between 1988 and 1989 periods thereby partially explaining the upsurge in morbidity in 1989. They were further analysed for the differences in cumulative exposure data from one year lag period. Such cumulative exposures above all possible permissible standards were derived and tested for differences in exposures. As the exposure concentrations became more acute subjects under the test groups showed significant differences thereby indicating possible association between pollution and general morbidity in high pollution zones.

Certain useful projections of trends in morbidity were also tried using Markov analysis for morbidity. The trends suggest that in the future, if the present trends of morbidity continue, only 56 % in the region will remain normal, 21 % (16 % from upper respiratory diseases and 5 % from Lower respiratory diseases) as having respiratory diseases and 3 % will be in cardio-vascular diseases. These estimates are based upon only the two time analysis of data, which perhaps may be too small an epidemiological information.

It is important to note that long term prospective air quality studies in relation to epidemiological investigations are desirable to analyse the data in better perspectives with greater reliability and reach more valid conclusions. This study is only a begining in this direction.

ANNEXURE I

I FAMILY PROFORMA

Date :

Date of consent
for doctors visit :
Time:

Interviewer:
FAMILY CODE

1.ADDRESS

2.NUMBER OF PEOPLE ABOVE 10 YEARS :

3.Economic Status : Code:

Total Annual Income

below 20,000/ 20001-40000 /40001 and above

4. Years of Stay at the above address

5 Yr / 10 yr/ 15 yr/ 20yr and above

5. Domestic Environment :

i) Number of Smokers in home: Office:

ii) Type of cooking fuel : cowdung cake/ charcoal/Lpg
(if necessory tick firewood/kerosene/electricity
more than one)

iii) Type of heating fuel : cowdung cake/ charcoal/Lpg
(if necessory tick firewood/kerosene/electricity
more than one)

iv) Type of House : hut/tiled/asbestos/RCC
Inside area of house: 4 or below/6/8/10/12/14/16 ...
(1SQ = 100 sq.ft)
vertical height : cellar/ground floor/I/II/III/IV

v) Type of ventilation:
No.windows : No.of doors:
Height of ceiling: Lower/normal/higher
(normal 10ft)

vi) Type of ventilation in kitchen:
poor/ moderate/ excellant

vii) General Characteristics of neighbourhood:
slum/congested/normally placed
spatial

viii) Volume of local traffic:
(No.of vehicles in an hour)

II INDIVIDUAL PROFORMA

(IN CASE THE AGE OF SUBJECT IS LESS THAN 10 YEARS AND LIVING IN THE PLACE OFRESIDENCE IS LESS THAN 5 YEARS PLEASE DONOT USE THIS FORM)

To be filled by one member of the family only

1. Name:
2. Age :
3. Sex :
4. Weight:
5. Marital status:
6. Smoking Habits: Y/N Cigerettes/beedies/ any other numbers per day
7. Drinking Habits: Y/N
8. Diet:
9. Occupation:
10. Duration of Stay (on a typical day):

    At Home : less than 5 hr/6/7/8/9/10/12/14/16/18/20

    At travel: 1/4 hr/ 1/2 hr/ 1.5hr/ 2hr/ 3hr/4hr/6hr

    At occupation: less than 4 hr/ 6hr/ 8hr/12 hr/16hr

    At recreation : Nil/ 1/2 hr/ 1 hr/ 1.5 hr/ 2hr

11. Type of transport :
    Route:

12. Type of occupational environment:

    i) Indicate the presence of industrial pollutants any.

    ii) If known, presence of specific occupational diseases by
    him/herself:
    his co-workers

III MEDICAL PROFORMA

Complaints :

H/O Presenting Complaints :

Past History :

Family history :

Personal History :

Medical Examination :

a) General

b) Respiratory

c) Cardio-vascular

d) C.N.S

e) Perabdomen

f) Skeletal

g) Skin

h) Any other

i) Abnormality detected/ diagnosis

ii) How did patients conditions differ from previous years with respect to signs, symptoms and disease on the whole:

Doctors Opinion: Same as before/ worst/ more worst/ better/ much better

Subjects Opinion : Same as before/ worst/ more worst/ better/ much better

iii) Medication History :

Clinical tests advised :

1) Blood: Hb %
TC
DC
ESR
AEC

2) Urine Albumin
Sugar

3) Biochemical tests

4) Radiographic

5) ECG

Doctor's signature

ANNEXURE 2

Table 1

I st Epidemiological Survey 1988, Diseases diagnosed
Chamarajpet and Cottonpet Divisions

HEALTH STATE	Frequency
Normal in 1988 and 1989	583
Normal in 1988 and diseased in 1989	152
Symptomatic	51
Anaemia	25
Allergic Rhinitis	23
Chronic Bronchial Asthma	22
Head ache (discomfort)	17
Chronic rhinitis	17
Mild hypertension	15
Repeated URI	14
Diabetes mellitis	13
Chronic bronchitis	13
Obesity	12
Recurrent Rhino Bronchitis	11
Acid peptic disease	10
Allergic bronchitis	8
Diabetes mellitus(NIDDM)	6
Essential Hypertension	6
Angina Pectoris	5
Essential HTN,Obesity	4
Hip fractured treated	4
Breast Cancer and others	4
NIDDM,Hypertension	3
Chronic bronchial asthma,mild HTN-essential,	3
Acute Rhinobronchitis	3
Back ache	3
Acne vulgaris	3
Rheumatoid Arthritis	3
Bronchial asthma c Allergic rhinitis	2
Myalgia	2
Allergic conjuntitis	2
Mental retardation	2
Adherant Leukoma	2
Congenital Aortic Stenosis	2
Enphysema	2
Pulmonary Tuberculosis	2
Acute bronchitis	2
Acute Pharyngitis	2
Acute Rhinitis	2
DM c HTN c Stress Ulcer, Psoriasis	1
Old bells palsy,DM,HTN	1

Paralysis,Diabetis mellitis,hypertension	1
Essential HTN,NIDDM,IHD	1
Recurrent rhinitis,acid peptic diseases,Albinism	1
Rhino bronchitis,HTN	1
Obesity c Headache(discomfort)	1
Oligomennohrea c Myopia	1
Headache c conjuctivitis(discomfort)	1
Diabetic Neuropathy c retinopathy	1
RHD MS c MR c PH	1
Pregnency 7th month c Anaemia	1
Gastritis c Anaemia	1
Essential hypertension,Obesity	1
Diabetes mellitis c Hypertension	1
Essential Hypertension c lower respiratory infection	1
Emphysema c Urticaria	1
Essential hypertension c Emphysema	1
Diabetes mellitus c Chronic bronchial asthma	1
Old Pul.Koch c Lumbar disc Prolapse	1
Acid peptic Disease,Old pulmonary Koch	1
Bronchitis acute gastroentitis	1
NIDDM,Bronchitis	1
Epilepsy c Bronchitis	1
Bronchitis,allergic conjuctivitis	1
Upper respiratory infection c allergic bronchitis	1
Chronic Bronchitis.,Smoker's Cough	1
Smokers bronchitis c gastritis	1
Migraine,Recurrent Rhinitis	1
Diabetic Mellitus Allergic Rhinitis	1
Allergic rhinitis,winter cough,old pulm Koch	1
Allergic rhino bronchitis	1
Recurrent Rhinitis/Sinusitis, fracture rib	1
Psoriasis	1
Aphthous stomatatis	1
Anobalic Dysentary mild dehydration	1
Alcoholic Hepatitis	1
Hypothyrodism	1
Hyperhidrosis	1
Tremors of hand	1
Deaf & dumb	1
Idiopathic Epilepsy.	1
Hirsutism	1
Dermatitis	1
Erythematus rashes	1
Fungal infection of skin	1
Sinus tachycardia,Anxiety state	1
Congestive cardiac failure,on Rx	1
Smokers cough	
Total	1104

Table 2

II nd Epidemiological Survey 1989, Diseases diagnosed
Chamarajpet and Cottonpet Divisions

HEALTH STATE	Frequency
Normal in 1988 and 1989	583
Normal in 1989 and diseased in 1988	81
Recurrent URI	113
Chronic bronchial asthma(extrinsic)	32
Anemia (I.D.A)	27
Acid peptic disease	15
Recurrent rhinitis	14
Refractory errors in eyes	13
Chronic bronchitis	13
sprain, dislocation joints, fracture	11
Essential HTN	11
Backache	9
Diabetes mellitus(type II)	8
Chronic bronchial asthma(intrinsic)	6
DM c Essential HTN	5
Allergic rhino bronchitis	5
Obesity	5
HTN	5
Epilepsy	4
Angina pectoris	4
Chronic sinusitis c URI	4
Allegic rhinitis and conjuctivitis	3
Recurrent rhino bronchitis	3
Allergic rhinitis c Recurrent pharyngitis	3
Rhinitis and pharyngitis	3
NIDDM	3
Rheumatoid arthritis	3
DM,essential HTN	2
Anemia c Pheripheral neuritis	2
Chronic bronchitis c DM	2
Anaemia c bronchial asthma	2
Bronchial asthma and essential HTN	2
Recurrent pharyngitis c anemia	2
Allergic rhinitis c acid peptic disease	2
Dysmenorrhea	2
Psoriosis	2
Migraine	2
Amebic colitis	2
Taenia Versicolor	2
Hyperthyrodism	2
Mentally retarded	2
Hypopigmented patches	2
Essential HTN c peripheral numbness c autonomic nervous syst	1
Leucoderma c fissue foot fungal infection c gastritis	1
Acute gastritis c myalgia c anaemia	1

Anemia c Veritego(non specific) c allergic dermatitis
HTN c chronic gastritis c acute gastroentitis c ovarien cyst
Obesity c hypothyroidism c HTN
Obesity c HTN c DM c Osteositis of left knee and burning of
Essential HTN c peripheral neuritis c myalgia
DM c Hypertension c old RF sided c Dysarthria
? IHD c peripheral neuritis c ?DM
HTN c obesity and ? IHD
Essential HTN c NIDDM c IHD
Essential HTN c emphysema c migraine
IHD c emphsema c peripheral neusitis ? in CCF
Uncontrolled NIDDM c retinopathy c ?vitreous haemmorage c pe
Peptic ulcer,Chronic bronchitis,Essential HTN
Chronic bronchitis c emphysema c chronic alcoholic
Tonsilits and Pharyngitis c HTN
UTI c gastritis c Recurrent URI
Chronic Rhinitis,Obesity c Reccurent Myalgia
DM(NIDDM) c Recurrent allergic rhinitis c Obesity
Warts,Allergic rhinitis and neurogenic deafness(left ear)
Allergic rhino brochitis c leucoderma
HTN,Simple chronic bronchitis,allergic rhinitis(?)
Recurrent allergic rhinitis and pharyngitis c migraine
Recurrent rhinitis c chronic sinusitis
Migraine,lumbar disc lesion (L5-S1)
Acid peptic disease,lumbarspondilosis
Chronic gastritis c vit difficiency
Irritable bowel syndrome, worm infestation
Migraine c UTI
DM c psoriosis
DM c obesity
Emphysema c urticarial rashes
NIDDM c peripheral neuritis
Obesity c peripheral neusitis
DM c peripheral neuritis c amputed lower 1/3rd of rt leg
Depression, headache c obesity
Fissure foot c exposure dermatitis
Anaemia c haemorrhoids
RHD MS c MR c PH
Anemia c gastritis
Anaemia c giddiness and nausea
Headache c anemia
Iron difficiency anaemia c HTN
Essential HTN c NIDDM
Obesity c essential HTN
? Coaractation of aorta c upper limb hypertensive c frontal
HTN c angina pectoris
CRF c HTN
Myalgia c recurrent LRI
Sino bronchial syndrome
Pulm TB c epilepsy
Chronic allergic bronchitis c hypothyrodin
Chronic bronchitis c polycythemia
Chronic bronchitis c ? mild HTN
Migraine c recurrent URI

Myalgia c recurrent URI	1
Recurrent attacks of URI,Acid peptic diseases	1
URI infection c warts c veruca vulgaris	1
Anemia c recurrent URI	1
Recurrent allergic rhinitis c DNS (left)	1
Allergic rhinitis c Obesity	1
Recurrent allergic rhinitis c potential diabetes	1
Allergic rhinitis c neurogenic deafness	1
Allergic rhinitis, ? haemorhoids	1
Anaemia c Weakness,recurrent allergic rhinitis	1
Bronchial asthma c Allergic rhinitis	1
Allergic rhinitis c bronchitis	1
Rhino bronchitis(allergic),genu valgan bilateral	1
Allergic rhinitis c sinusitis	1
Acute nasobronchial allergy c sinusitis	1
Chronic sinusitis c allergic bronchitis, smoker's bronchitis	1
Myalgia	1
Gastritis	1
Essential tremor	1
Vertigo (non specific)	1
Allergic conjuctivitis	1
Melanosis	1
Hirusitisun	1
Congenital aortic stenosis	1
Varicose veins in the (L) leg	1
Hemorrhoids	1
C.C.F	1
Pulmonary TB	1
Chronic tonsilitis	1
EXPIRED on May 1 st 1989, URI	1
Total	1104

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